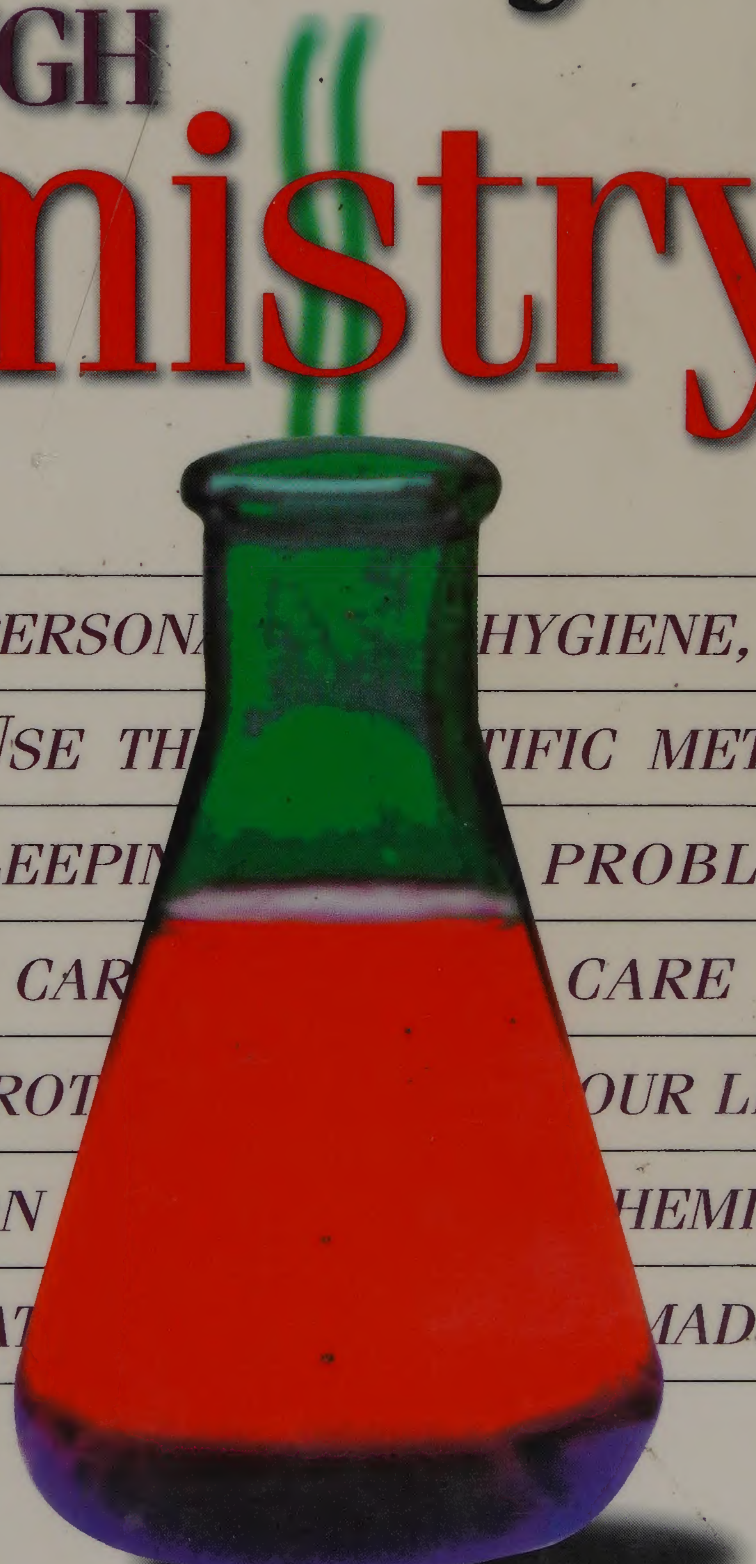
# Save Time and Money through Chemistry



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Ken Carpenter

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Ken Carpenter

Useful Chemistry Publishing
Dayton, Ohio

Dedicated to my high school chemistry teacher, Mr. Barney who made chemistry understandable.



**International Standard Book Number:** 0-9655667-1-4
**Library of Congress Catalog Card Number:** 96-90852

Published by Useful Chemistry Publishing
P. O. Box 31470
Dayton, OH 45437
(937) 252-6399
usechem@rcinet.com



## Acknowledgments

The author wishes to express his gratitude for the help of Betty Frecker & Associates, Fred Seibert, and Dr. Daniel M. Ketcha. Without their help, many errors would have gone unnoticed. Of course, any errors that remain are solely the responsibility of the author, Ken Carpenter.

Thanks to Chas Stough for his words of encouragement. Also, very special thanks go out to the 159 high school science teachers who responded to a survey of what they would like to see in a chemistry book. Many of their suggestions helped guide the writing of this book.

## Disclaimer



**Printed in the United States of America**
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# Contents at a Glance

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# Chapter 1

# Saving Time and Money through Chemistry

## Why Learn Chemistry?

Welcome to a new way of thinking about chemistry! Why learn concepts the greatest minds in history spent many lifetimes to create but seem to have no known applications to living (except for a small number of chemists who use them constantly)? Instead, you will learn how to use some of these basic rules of nature to solve problems of personal finance. To put it simply, the more you know about the world around you; the easier it is to save both time and money.

### The jack-of-all-trades versus the specialist

A fair question to ask is, "Why should I learn any chemistry? After all, my dad went through his whole life without a chemistry course." (Of course, this is not a question that the daughter of a chemist is likely to ask!) Most people come from families that may be very smart, but not gifted in the sciences.

People should learn a little chemistry for at least two reasons. First, most people who live and do things for a while gradually learn more and more about chemistry. Most middle-aged people probably know more basic chemical ideas than many college chemistry students. These old dogs simply have more "common sense." They know useful things about common chemicals in their kitchens, garages, swimming pools, and homes. They may not know the scientific jargon, but they know what these chemicals can do.

This book teaches some of this common-sense type knowledge. Also, a little jargon is introduced so that the readers can talk with the experts.

The other reason to learn some chemistry is that the work world has fundamentally changed in the last 30 years or so. The computer has made expert skills less valuable.

This is actually the third major change in the nature of work since the Renaissance. The first major change was the invention of the printing press. This change made memory less important because all the person would have to remember is where he/she left the reference manual. This is a far easier task than remembering its entire contents!

The second change was the assembly line and specialization of labor. This made the specialist, someone who is very good at one thing, a very valuable member of a team. The path to success for most people was to learn a lot about one thing and then hope to get hired to do it.

All this changed with the invention of the computer. The computer is the ultimate specialist. The best experts can quickly teach it. Also, it can use a wide variety of attachments as needed for a job. A printer can replace a secretary at typing. A robot arm can replace an assembly person. Because of the computer, the Age of the Specialist is over.

Currently, computers have a problem learning. A computer will mindlessly do the same task over and over until it is reprogrammed. This has created a little period of time (until computers can think for themselves) when most people are employed for new ideas and creativity.

One of the best ways to create a new idea is to apply something from one field to another. The fewer people who know the outside field; the more original the new idea is likely to be. The concepts of chemistry are useful and powerful by themselves. However, in the Age of Imagination, these concepts are more important than in the simpler world of the 1950s when your parents were young.

## Chemicals

A chemical is anything that takes up space. Combinations of simple chemicals make up all types of matter and materials. These chemicals come in a wide variety of flavors and colors.

### Natural versus artificial chemicals

Many chemicals came from nature long before humans learned to re-create them. Simple chemicals such as water are common on earth and even in space. Plants and animals produce many complex chemicals such as cholesterol or vitamin C. Mother Nature invented these materials billions of years before humans invented the test tube.

"Artificial" simply means "made by humans." However, it is sometimes hard to tell the difference between "natural" and "artificial."

Artificial chemicals are the same in every possible way as those found in nature. For example, artificial water is the same color and flavor as rain water. The body uses artificial water in exactly the same way as river water. The reason for this is that water is water no matter where it comes from.

Some con artists have made a living by pretending that natural and artificial chemicals are different. This distinction is as silly as disliking the number 8 when it is found by adding 5+3 instead of adding 4+4. The number 8 is always the number 8. Likewise, a chemical is a chemical no matter where it is found or how it was created. For this reason, a label saying that the product is "all-natural" should not be a factor in choosing to buy it. Natural products are often no better than artificial products in the areas of safety, good taste, effectiveness, or promoting a clean environment.

If you believe that all natural things taste good, try eating a truly hot pepper sometime! Even worse, deadly poisons occur in many plants, animals, and germs. For this reason, natural products are not always safe. Purifying artificial mixtures is often cheaper than removing the poisons from natural sources. Finally, even farmers using "natural" methods can cause damage to the environment if they allow deadly pests to breed.

In addition to re-creating chemicals found in nature, labs can also make chemicals that Mother Nature never found a use for. I have made about 30 chemicals unknown anywhere else in the world. Many chemists create hundreds over a lifetime.

Even though these chemicals are new and not found in nature, they are rarely any more dangerous than most materials. Even with all of the millions of new chemicals, it turns out that one of the deadliest poisons comes from a South American frog. The reason is simple. That species of frog has been working for millions of years to produce a poison so deadly that it can live a long life (more than five years) with few predators. Very few animals can eat these toxic frogs. While the frog has been working on its poison for millions of years, humans have been working on poisons for much less time. The frog poison is not an isolated case. For the same reason, many of the deadliest chemicals come from the natural world.

Also, artificial chemicals cause only a small fraction of the cases of cancer. These chemicals have a bad reputation mainly because they are tested more often than natural chemicals. Soot from chimneys can cause a form of cancer. Is that a reason to stop building fires? Other causes of cancer include foods, viruses, tobacco, and genes.

Cancer was around long before humans made any new chemicals. In the past, people thought it was due to witchcraft.

## The Factors Behind a Buying Decision

The three basic factors in any purchase are price, quantity, and quality (which includes whether it is in fashion). These factors can be combined to give other factors.

For example, when you divide price by quantity, you obtain a very important number called "price per unit" — such as $1.06 per pound. A dollar is a unit of price while a pound is a unit of quantity. In this case, the ratio is the price of one pound of mass. (On Earth, the terms of "mass" and "weight" are sometimes used to mean the same thing.)

Another important ratio is quality divided by price. The units for quality are a little troublesome. I like to think of quality as how much you would pay, given the alternatives available. Perhaps a well-tailored suit that lasts two years is worth about $500 to you. If it is on sale for $300, the ratio would be $500 worth of quality for $300 of price or 1.66. The bigger this ratio is; the better the deal.

### Urgent needs and quality

An urgent need can affect the perceived quality of an item. For example, it is important to eat a filling meal before food shopping. A hungry person views food differently from the way a well-fed person views it. Someone who is hungry is more likely to buy quick energy foods such as candy or doughnuts.

At The Ohio State University (OSU), there were a lot of panhandlers along the edge of campus. Rather than just give $5 to one of them, I walked with him to a nearby store to see what he would buy. He bought coffee and a pack of glazed doughnuts. He was apparently very hungry and put great value on quick energy. This made the doughnuts look like a very good buy.

### Labels

There are a lot of labels to read nowadays. If you spent all the time reading high-quality books that you spend reading signs, contracts, labels, and newspapers, you might be in *Who's Who* where those people read an average of 20 books a year. However, you might be dead from drinking paint against the advice on the label. Still, the maker of the product knows more about it than anyone else. Labels are a useful way of transferring that information.

Fortunately, labels are printed in the native language of the country where the products are sold. If you have made it this far into the book, you can understand most labels. However, some labels (such as a list of ingredients) can have a lot of annoying jargon on them. The best rule to

follow is that if you cannot read the jargon, judge the product on what you do know. You can always sue later.

### Warning labels

While warning labels are more common than ever before, their usefulness has gone down. Guess where this label may go: "Warning: Can cause asphyxiation. Corrosive. Reacts violently with alkali metals. For purposes of complying with the New Jersey Right to Know Act, contents partially unknown."

If you guessed tap water, you are correct. Unfortunately, too many people follow the advice of the last section and sue the product maker. To protect the sellers, warning labels cover almost every package — making it difficult to tell which products are the most dangerous.

### Generics

Brand-name products usually have a history of quality. The soap from Procter & Gamble has been of high quality for so many years that it has developed a loyal following. However, these shoppers tend to pay extra for soap.

Store brands or generics (products that do not give the name of the maker) are often made from the same materials and processed the same way as the more costly brand-name products. Sometimes, it is even the same product made by the same company because name-brand manufacturers will often make generics as well.

If you do not mind once in a while getting stuck with watered down or poorly made generics, the savings over the major brands can be substantial. The brand-name version often costs more than twice as much as the generic.

### Decide on the units

When shopping, decide whether you are interested in mass, volume, number, memory size, or whatever. Divide price by the units of quantity to get a ratio that is one factor in deciding whether to buy. Hard drives would be in units of dollars per megabyte. Food would be in dollars per pound or dollars per calorie. Calculators would be in dollars per function or (if it is just to impress coworkers) dollars per button.

### Mathematics of the buying decision

Math is used in almost every decision in life — including shopping. However, the most useful math is very simple. Algebra is used in only a tiny fraction of all decisions and calculus is used even less. The decision often comes down to the simplest type of math — counting. Many people

decide against buying a car by comparing its price to the amount in their savings account. This is truly math at work!

One type of math belongs in geometry courses, but most people only learn about it in science courses. It is called "dimensional analysis," and it helps people deal with numbers that have units. Dimensional analysis can help in far more situations than a good working knowledge of algebra.

Suppose you weigh 150 pounds. If you are six feet tall, how much do you weigh per inch? The answer to this question can be found in a very systematic way using dimensional analysis. The key is to set up a chain of conversion factors, such as one foot equals twelve inches, and then cancel units to obtain the correct number in the right units.

The result from the calculation should have units of pounds per inch. Equation 1-1 shows the method to be used. Just divide the weight by the height. An answer in the units of pounds per foot is the result. Remember that the answer should have the units of pounds per inch. To change the units of feet into units of inches, multiply the first answer by a conversion factor of one foot per twelve inches as shown below. You can imagine that the ft's cancel out just like fractions.

$$\frac{150 \text{ lb}}{6 \text{ ft}} \text{x} \frac{1 \text{ ft}}{12 \text{ in}} = 2.08 \text{ lb per inch (Equation 1-1)}$$

Like all other types of math, dimensional analysis requires a lot of practice to learn. One more example (this time related to shopping) will be given here. To really learn this concept, the reader will have to answer the questions at the end of this chapter.

Suppose you have the choice between buying shampoo in the economy size of 70 ounces per bottle or buying three small bottles of shampoo on sale. The economy size costs $2.59 per bottle. The small bottles have to be purchased together for $1.76 and each bottle contains 23 ounces. Which deal has the lower price per ounce?

The price per ounce for the economy size is found simply with dimensional analysis. The units desired are dollars per ounce. Dividing the price of $2.59 by 70 ounces gives the number 0.037 in units of dollars per ounce. (See equation 1-2.)

$$\frac{\$2.59}{70 \text{ ounces}} = 0.037 \text{ dollars per ounce (Equation 1-2)}$$

The price per ounce of the three-bottle deal requires a little canceling out of units. As always, before beginning work, decide the units

you want for the answer. In this case, units of dollars per ounce are easy to compare to the result for the economy size. You also have a conversion factor of one bottle is 23 ounces. Equation 1-3 shows how to get an answer of 0.026 dollars per ounce. This is a lower price per ounce than the economy size.

$$\frac{\$1.76}{3\text{ bottles}} \times \frac{1\text{ bottle}}{23\text{ ounces}} = 0.026\text{ dollars per ounce (Equation 1-3)}$$

Note that bottles cancel out in equation 1-3. Also note that stores usually price larger packages at a lower price per unit. In the last example, the store cut the price of the small bottles to get rid of excess inventory. This sometimes happens in real life and points out the benefit of running the numbers instead of just buying the large size without thinking.

## Buying in bulk

You will usually find that the large size is cheaper per unit. If so, buy as much as you need in the large size. If the small size is more convenient, it is sometimes possible to buy a small container and refill with a large size as needed. However, this does not work so well with deodorant spray or toothpaste.

There happens to be an excellent reason why buying in bulk is cheaper. When you buy more than you need, storage costs can become expensive. If you buy so much stuff that your car no longer fits in the garage, part of the storage costs would be the extra wear on the car from the weather. The storage costs would also include the time it takes to scrape ice off the windshield in the winter.

Space in the refrigerator is often quite precious. When you buy an extra two pounds of steak on sale, the space that the steak takes up could have stored lettuce that also might have been on sale. If your refrigerator and freezer are almost full, it might be worthwhile to see whether buying the steak or the lettuce would save more money. The storage cost of the steak would be the savings lost by not buying the lettuce at the sale price.

If the price of an item is about to go up, it makes sense to buy more than usual. During periods of inflation, this practice becomes quite common. Stocking up before a price increase is called "hoarding." Hoarding has the side benefit of protecting against shortages that often occur when price controls are imposed. When prices are rising, you should use all the storage space possible for hoarding.

When something can be stored at room temperature, leave it out of the refrigerator until it needs to be cold. For example, most people like their soda pop cold, but leaving the cans or bottles in the refrigerator takes

up a lot of space. A better idea is to put in as much as needed for a day or two. The extra space can be filled with items that need to be cold. If unexpected guests arrive, ice cubes from the freezer or a store will quickly lower the temperature of soda pop. (However, fewer people like ice cubes in their beer.)

The biggest problem of buying in bulk is that without careful management much of the stuff will go bad before it can be used. Refrigerated (unfrozen) meat may last less than a week, eggs will go bad in a month or so, fruit may last two days to a month, and most other items will also go bad eventually. Some products give expiration dates and these are very helpful because they tend to be accurate. If food is about to expire, it should be either used or thrown out.

Sometimes the cheapest way to purchase products in bulk is to share them with friends and neighbors. When apples are in season, it is sometimes possible to buy 50 pounds of apples for a few dollars. By sharing the apples with four other families, each family can have about ten pounds for a dollar without worrying about the apples going to waste.

### Installation

Where to put an item can be an important factor in deciding whether to buy it. If an apartment is too small or too full of furniture, there may be no place to put a big computer or stove. This sort of problem is easy to spot.

Other sorts of installation problems may be more difficult to foresee. If another country uses a power supply with a different voltage or cycles per second, electronic goods from that country may need special gadgets to work on the power supply in the United States. Electronics from the United States may have similar problems overseas.

Heat can also be a problem. The second law of thermodynamics says that a refrigerator has to work harder if it is surrounded by warmer air. A one-degree increase in outside temperature costs about as much energy as a one-degree decrease in the refrigerator's thermostat setting. Each degree increase in outside temperature requires roughly a 2% increase in power for the refrigerator. This can mean about a 1% increase in the electric bill if the air around the refrigerator is kept five degrees warmer than the rest of the house (perhaps due to direct sunlight or a nearby stove). It may be possible to save $10 a year in electric costs by moving the stove a little farther away from the refrigerator or putting a thin piece of insulation between them.

### Care of purchases

Many goods require care long after the money has changed hands. Some of this care is well known or is quickly learned after owning the item for a while. Almost everyone knows that clothes must be cleaned frequently to remain wearable. (It is not pleasant to be downwind of people who do not know that!) Cars require regular servicing. Homes need many hours a month to maintain.

When purchasing something, try to estimate the cost in terms of time and money to take care of the item. Maintenance costs must be considered before buying a product. Compare these costs with your schedule and budget to see if you can afford the item. If a shirt must be dry-cleaned after each wearing, it is probably more costly than a shirt you can just throw into a washing machine. Some families where both the husband and wife work may need to hire a maid and a gardener in order to maintain a house. These sorts of costs should be considered as part of the purchase price.

Some costs are hidden and difficult to estimate. Even a refrigerator could use some care. Regularly cleaning the gasket — that plastic strip between the door and the rest of the refrigerator — can reduce the flow of warm air into the refrigerator. Also, dusting the coils that exchange heat between the refrigerator and the outside can reduce the amount of energy required. Both of these items take time but can reduce energy bills. People short of money but not time may wish to do more preventive maintenance like this.

## Penny Wisdom

Penny pinching is the saving or earning of very small amounts of money. An example of earning small amounts of money would be bending over to pick up pennies. An example of saving money by penny pinching is taking an extra minute to scrape out food from the bottom of a pot. In both cases a small amount of thought and effort is transformed into a small amount of extra wealth.

The key to successful penny pinching is being prepared. Chances to earn tiny amounts of wealth come very often compared to winning the lottery. A penny-wise person must know what to do quickly when a chance for wealth arises.

If you spend most of a day walking around looking at sidewalks, you might discover three pennies and a dime if you are lucky. Of course, no one can earn a living doing this. However, what would you do if you happened to glance down and see a penny?

Many people would bend down (possibly risking back failure), pick up the penny (getting their hands dirty), and slip it into a pocket. The operation might take 30 seconds from seeing the coin to placing it safely in a pocket. The key question is how much was the lucky finder of the coin paid for his or her time? Thirty seconds is 1/120th of an hour. Since the coin was a penny, 120 pennies could be picked up like this over an hour. This means that the lucky finder of the penny was earning $1.20 an hour for the good fortune of discovering the coin. If the finder had worked out the math of picking up pennies ahead of time, most likely he or she could have thought of something more useful to do for those 30 seconds.

Sometimes the extra effort to save pennies is worth it. Suppose that an expensive food worth $3 per pound in time and labor is transferred from one dish to another. One way to transfer the food would be to leave big chunks of food behind on the original dish. The other way is to spend an extra minute and scrape off all the large chunks. The difference might be as much as 1/4 ounce. Working the math before the decision comes up is the most intelligent way to handle the problem.

At $3 per pound, the food is worth about 19 cents per ounce. The one-quarter of an ounce saved by scraping is worth $0.19 divided by 4 or about a nickel. If it takes a minute to scrape the dish, that means that the time was rewarded at about $0.05 per minute or about $3 per hour. (See equation 1-4.)

$$\frac{0.25 \text{ oz}}{1 \text{ minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times \frac{1 \text{ lb}}{16 \text{ oz}} \times \frac{\$3}{1 \text{ lb}} = \$2.81 \text{ per hour (Equation 1-4)}$$

(Notice how much simpler the dimensional analysis is than the written description of the same calculation! The problem gives the ratio of one-quarter ounce per minute. Multiplying this ratio by conversion factors of time into hours, ounces into pounds, and pounds into money changes the units into dollars per hour and quickly gives the correct answer.)

Three dollars per hour may still be too little for the extra time and effort. For most people, scraping can save money, but it must be done quickly. If scraping the dish only took ten seconds, the rate of reward would go up to $18 per hour. Another way to justify scraping the dish is if several things were cooking at the same time and if the cook could monitor all of the other dishes while scraping.

These examples show how easy it is to be "penny-wise and pound-foolish." The key is to be prepared for opportunities when they appear.

## The Scientific Method

Scientists and philosophers have created a method of finding and using knowledge called the scientific method. Scientists have used it for many years, and the results have been spectacular. The method can be useful for anyone.

It starts with a goal. The goal for professional scientists is a fuller understanding of how the world works. For example, a scientist may decide early in his or her career to study the sludge on river bottoms.

After the goal is selected, the scientist collects vast amounts of data. He or she would read as much as possible about river sludge around the world — especially rivers upstream from his or her river. Often, the scientist will find the reading is very technical — such as the chemical content of soils. However, other data may be easier to understand. In any case, he or she must learn as much as possible from what other people have done.

Next, the scientist gathers information from the river and from samples of sludge. Chemical tests on the sludge are important as is a study of the life present in the sludge. The scientist would measure wind speed over the river, the depth of the river, and water speed at various levels over the sludge.

As the data is collected, the scientist searches for patterns and usually finds some. Maybe when the river is high, the sludge develops a layer of sand over it. Perhaps the variety of life in the sludge increases when a factory upstream dumps waste into the river.

These patterns are used to form educated guesses, called "hypotheses." (A single educated guess is called a "hypothesis.") For example, the height of the river may indicate that the sludge should contain 50% more sand in it this year than last year. The scientist would test the river to see if his or her hypothesis was correct. The hypothesis becomes a theory if it successfully predicts the sand content of the sludge.

A better theory would explain this pattern. When the river is high, maybe sandy dirt from the river banks falls into the water. Alternatively, perhaps the water speed increases as the river rises, and sand from upstream drops onto the sludge. These explanations are really new hypotheses. The scientist would test them to improve the "sandy-river-bottom" theory. Maybe dyeing the sand upstream blue and the sandy dirt on the banks red could show the origin of the sand.

Somehow, any new theory will prove useful. There is no such thing as a useless law of nature. For example, suppose a new dam is proposed someday to generate electrical power from the river. The scientist will be able to help plan the project so that the fishing in the resulting lake will be

more profitable. The "sandy-river-bottom" theory could be used to predict how much sand will flow into the lake and how much extra sand may have to be added.

This same scientific method of gathering facts, searching for patterns, forming theories, and using the new knowledge is used by most experts in most fields — even fields that have little to do with science.

Cooks use it to perfect their recipes. They consult cookbooks for published recipes. They see what happens when the amount of salt is doubled or halved. They use this new theory to improve the flavor of their final dish.

Business owners read newspapers for new ideas. They study how the business climate affects their company. Their theory of how the company will do in a poor economy may cause them to reduce their debt.

Baseball players study how the swing impacts on the ball. They study films of great hitters and films of themselves to discover what makes a great swing. They develop a hypothesis of how to improve their swing. They test the new hypothesis to see if it improves either the distance or the placement of their hitting.

The scientific method is a powerful way to use information. It can provide insight into what is apparently a jumble of nonsense. This is why most experts use it.

If you want to save time or money, you cannot skimp on research about how time or money is spent. You will need to find patterns in how you use time or spend money. The theories from this study can show you how to save money or use time more wisely. Collecting information is the first step in budgeting money or scheduling time.

As a rule, scientists apply the scientific method to their daily life — often testing theories when they can. Everybody can sometimes benefit from testing theories. However, the results will probably not be as spectacular as when George de Hevesy (a Nobel Prize-winning chemist) stayed in an inn.

He suspected that the food was of poor quality. So, he did a little experiment. He left the fatty portion of a piece of meat uneaten at the side of his plate. When no one was looking, he covered it with a little radioactive material. He then left the table.

The next day, the inn served a meat hash for dinner. Hevesy took out his Geiger counter that can detect radioactivity in nearby materials. He found that food was very radioactive. He quickly guessed that the inn was reusing table scraps from the plates of guests (including the radioactive fat from the day before). He immediately checked out and found another inn.

Other people are not likely to run experiments as close to the frontiers of science. Most experiments are along the lines of writing "Wash me" on the sides of a dirty car to see how long the owner takes to clean the car.

## Skepticism

Skepticism is an attitude common among scientists that can be helpful to shoppers. Skepticism is a distrust of statements and beliefs that have not been tested by the scientific method. Furthermore, just because someone says that his or her statements are based on scientific studies does not mean that they are worthy of belief.

Two problems often cause theories to be wrong. The less common problem is poor or unlucky testing of the theory. Sometimes the experiments used to test a theory reflect some outside factor rather than supporting the theory. This was the problem with the old "phlogiston" theory where burning things seemed to react with a strange "essence." The experiments that "proved" the old theory were all done in air rich in oxygen. A chemist named Antoine Lavoisier was able to refute the theory using sealed tubes filled with various materials and a limited supply of air.

When a theory is disproved, it must be replaced by a new one. The phlogiston theory became the theory of oxidation.

The testing of a theory can also go wrong by taking too little data. With few observations, chance can often determine the result of a study. For example, just because a couple of friends are sick does not always mean that there is an epidemic.

While the above mistakes can result in incorrect beliefs, they are less common than another human failing. Human beings tend to tell lies. In the 1990s, the people in the United States often lie. While the 1980s was called the Decade of Greed, the 1990s should be called the Decade of Fraud and Deceit.

Whenever there is an advantage to lying, some people will give it a try. Many ads will say anything to sell the product — even if some things said are not totally true. Even scientists have been known to lie sometimes. Scientists tend to publish anything that will renew their grants. Tobacco companies often hire only scientists who believe smoking is almost harmless. In the early 1990s, Congress gave free publicity to doctors trying to ban tobacco. This may help to explain why so many "experts" on smoking were arguing with each other.

Be on your guard when someone stands to gain by lying. Many people are very honest, but some are not so trustworthy. If possible, decisions should be based on more than one source. An even better idea

for very important decisions is to test the statements using the scientific method. However, trusting *Consumer Reports* or other testing services is often good enough and saves some time and trouble.

## Do-It-Yourselfing

Many money-saving books advise doing things yourself. Car books give tips for changing the oil or replacing the brake pads. Gardening books show how to grow your own food. Cook books teach how to cook food. Home medical books help you avoid trips to the doctor.

To benefit from these books, you must learn a simple economic fact. The job will usually take longer and cost more the first time you do it instead of taking it to someone who has done it before. That is why people specialize in cooking food, repairing cars, and farming. No matter what you do, if you are competing against experts, do not expect to beat them on the first try.

This does not mean that do-it-yourselfing is doomed to be a time and money waster. If the first oil change pollutes the area around your garage, permanently stains a good T-shirt, takes eight hours, and requires ten quarts of oil, just consider that to be the cost of an education. Next time, there will be less pollution, a used T-shirt to wear, quicker execution, and less oil spilled. It is unlikely that you will ever be as good as a typical mechanic. However, you will be able to change the oil when all the repair garages are closed. Also, you will be able pick from a wider selection of brands of oil.

When you are learning to cook, the meals will take more time and cost only pennies less than throwing TV dinners into the microwave. However, you will soon be better able to spot bargains and be prepared to cook cheap meals around those bargains.

Any form of do-it-yourselfing will cost lots of time and money during the "education" phase but will later pay some returns in better service, lower cost, or a new job. If you become good at a new line of work, you might have a new career.

### Raw materials

Raw materials can limit the savings from doing something yourself. For example, the ingredients to a recipe sometimes cost more than buying the TV dinner. While the do-it-yourselfer only needs a little of each raw material, a business often has machines to process the same materials bought in bulk. With large discounts on materials and little labor, a business can sometimes make items at unbeatable prices.

A good way to avoid wasting time and money on no-win projects is to calculate all the costs at the end of a project. If you saved a little money but took too much time (the usual result), it may be worth doing again because everybody gets faster and better with practice. If the raw materials cost more than someone else would charge to do the whole job, it may be better not to do it yourself.

A good strategy for do-it-yourselfers is to buy used goods and tear them apart to reuse the fabric, wood, glass, automotive parts, electrical parts, etc. Even if the used item cannot be fixed, the materials may still be worth something. Sometimes the fabric in used clothing or the wood in used furniture may be a bargain compared to buying the material new.

Consider what uses cheap materials might have. If nothing else, an old shirt with holes in it can be cut into disposable rags. An old newspaper can help start a fire. Empty jars can be used as cups or food containers.

Usually, you will not want to make the raw materials yourself. For example, denim cloth from blue jeans is very common in used-clothing stores. However, it would take a lot of work to make the cloth at home.

Cotton is spun into threads. The threads are quickly dipped eight times into indigo dye — each time waiting for the yellow dye to turn blue in the air before dipping it again. A large automated weaving machine uses a three-on-one twill weave to combine the blue threads with white threads. Later, the fabric is cut up, sewn together, and rivets applied to the pockets.

Making fabric like this would be far too much work with too little payoff to save any money. Some things are better left to automated assembly lines.

## Mass Conservation

An important law of chemistry is that matter is neither created nor destroyed. This is called the law of mass conservation. It is mostly true. If you destroy a city with an atom bomb, a little matter will be converted into energy. It does not happen often in your car or at your house!

The reason the law of mass conservation is so important is that it lets you do a variety of useful calculations. For example, suppose you have five ounces of gin and one ounce of vermouth. How many ounces of a martini do you have? The answer is six ounces. No mass was lost by mixing the liquids together. (Some of the volume and/or flavor may have been lost, however.)

### Cost of ingredients

Finding the cost of ingredients uses the law of mass conservation and is very important for cooking. The cost of ingredients tells the cook

whether it is cheaper to cook a meal or order a pizza. After every new recipe, the cook should write down how much of each ingredient went into the dish and what the cost of each ingredient was. The costs of the ingredients are added together to find the cost of the dish, the cost per pound, and the cost per ounce.

Suppose a shortbread recipe calls for one stick of butter ($0.30), two cups of flour ($0.18), one half cup of sugar ($0.15), and one egg ($0.05). To calculate the cost per ounce, add up the cost of the ingredients and divide by the estimated weight. Altogether, the ingredients weigh roughly a pound and one-half. (See equations 1-5 and 1-6.)

$$\text{Total cost} = \$0.30 \text{ (butter)} + \$0.18 \text{ (flour)} + \$0.15 \text{ (sugar)} + \$0.05 \text{ (egg)}$$
$$\text{Total cost} = \$0.68 \quad \text{(Equation 1-5)}$$

$$\frac{\$0.68}{1.5 \text{ lb}} \times \frac{1 \text{ lb}}{16 \text{ oz}} = \$0.028 \text{ per ounce (Equation 1-6)}$$

The weight of the final product can often be estimated by the law of mass conservation. The butter weighs about four ounces, the flour weighs about sixteen ounces, the sugar weighs about two ounces, and the egg weighs about two ounces. Since this recipe is fairly dry, the loss in weight from evaporation of water or other liquids is small. The weights are simply added together to find 24 ounces of final product. Dividing the total cost of the ingredients ($0.68) by the weight (24 ounces), a cost per ounce of $0.028 is found. (If you have skipped over equations 1-5 and 1-6, now might be a good time to go back and look at them.)

If the shortbread from that recipe tastes good, the cook will save a lot of money. A cost per ounce of less than three cents is much cheaper than buying the cookies in fancy packages.

## Recycling

Recycling is currently popular. However, these efforts have met with only mixed success.

Iron is easy to recycle. Magnets can draw chunks of iron out of a huge pile of plastics, fabrics, glass, rocks, and other metals. At a dump, a single electromagnet can profitably gather tons of iron and steel to be melted and reused. (Steel is mostly iron.)

Aluminum has also been successfully recycled. Used aluminum cans are often worth between one penny and five cents (depending on the local laws). These cans have value because making aluminum from bauxite

requires lots of electricity. It is much cheaper just to melt old cans and turn them into new cans.

Glass can also be melted and reused. However, recycling glass is not as economical as recycling aluminum because it is also easy to turn sand into glass. Sand does not need the costly treatments that bauxite requires. Also, sand is dirt cheap — mainly because much of the world's dirt is made of sand.

The recycling of paper often does not save any money. It is hard to separate used paper from the dyes and coatings often found on paper. Recycling requires carefully sorting the papers and only recycling paper nearly free of coatings. Even with careful sorting, the recycled paper often comes out an off-white color. It is usually cheaper and better for the environment just to grow another tree. Many times, the best way to recycle paper is to use the back of the paper as scrap paper.

Polymers (also called "plastics") are hard to recycle. The problem is that the plastics need to be separated from each other because each plastic recycles unlike any other plastic. If recycling begins with a mixture of plastics, a nightmare of a mixture is likely to result. One of the most time-consuming jobs for a chemist is changing a complex mixture into pure materials. It is far cheaper to just pump some oil out of the ground, refine it, and change it into plastics.

However, this is largely just a technical problem. It is possible that a simple method of changing plastics back into fuel will become economical. For now, recycled plastics tend to be of lower quality and are more expensive. To dispose of a ton of plastic in the United States requires about $100. In contrast, the cost of changing used plastics into new plastic items is around $1,000 per ton.

## Shopping to Minimize Energy Costs

Over the length of service of some appliances, energy costs can be one to three times as much as the cost of purchase. Freezers, refrigerators, and dryers are some examples of this. A car's lifetime gasoline costs can be as high as $5,000. Buying energy-efficient gadgets can save hundreds of dollars per year.

Since old machinery from the 1970s was not designed for energy efficiency, it may actually cost more money to buy these gadgets used than to buy new. This is less likely to be true for cars. Cars lose so much value in the first couple of years, and expenses such as insurance are more important than gasoline cost. However, old refrigerators can cost a lot of money in electricity bills because they require a lot of power and are always on.

Chest freezers are usually more energy efficient than upright freezers. In part, this is due to extra insulation in the walls of the chest. Also, less cold air — which is denser than warm air — spills out when a chest is opened.

A little energy can also be saved by packing a freezer full of food or ice. The food or ice warms more slowly than cold air and reduces the cooling energy needed.

If you have a microwave oven, use it whenever possible. It is far more energy efficient than a conventional oven or stove. In a microwave oven, the only thing that becomes really hot is the food. With conventional heating the whole oven or stove top becomes hot and sometimes the whole kitchen as well. (If you can't stand the heat, get a microwave oven!)

Microwave cooking uses less than half as much energy as a conventional cooking. When you consider the cooking time that it also saves, microwave ovens are a bargain.

Although self-cleaning electric ovens use a lot of energy while they are cleaning, chemical cleaning usually costs more. If your oven gets dirty often, probably the safest, least time-consuming, and money-saving best choice is to use a self-cleaning oven. Be sure to turn on the self-cleaning right after cooking a meal while the oven is still hot. This helps the oven warm up to cleaning temperature.

On any gas-fired appliance, the pilot light costs $25 to $30 per year. Use this cost to compare the costs of pilot light versus electronic ignition models. The pilot light keeps a little flame lit all the time whether you use it or not. By buying the electronic ignition, you avoid paying for the gas this flame consumes.

A dishwasher with an energy-saving setting can save over $10 per year in utility bills. A dishwasher with a booster heater lets you run the water heater of the house or apartment at 120 Fahrenheit instead of 140. The lower water temperature may reduce the electric or gas bill by $20 per year. Just turn down the temperature on the main water heater.

## Energy units

Energy can be measured with any of several units. A common unit for energy in the USA is called a British thermal unit (b.t.u.). Actually, the British and most people other than engineers no longer use this unit. It takes one b.t.u. to raise the temperature of one pound of water by one degree Fahrenheit.

A food calorie is the amount of energy it takes to raise the temperature of one kilogram of water by one degree Celsius. This definition is a bit like how the b.t.u. is defined. In fact, if you multiply the

number of b.t.u.s by 0.252, you get the number of food calories. One food calorie is equal to 1,000 calories that chemists use.

## A Nonrenewable Resource

Guess the most nonrenewable resource:

1) Oil reserves
2) Rain forests
3) Wetlands
4) Time

If you chose anything but time, you will profit greatly from a little chemical knowledge. It is relatively simple to change carbon dioxide and water back into oil (using nuclear power) and shove it back into the ground — compared to replacing a single lost second. Rain forests will grow back in thousands of years (maybe faster with a little help from humans), but you can wait forever and a wasted day will always be lost. To recover a wetland, just add water. However, no potion will bring back a wasted youth.

### The units of time

Time is a widely known quantity that has few units. For quick actions such as dialing a phone or sprinting, the best unit is seconds. Minutes are used for the longer time periods needed to cook a meal or drive to work. Other units of time include a microsecond (one millionth of a second), a millisecond (one thousandth of a second), an hour, a day, a week, a fortnight (two weeks — a favorite unit for reference manuals), a month, a year, a blue moon, a decade, a century, a millennium, and when the cows come home.

### Converting between the units of time

Dimensional analysis can convert the units of time just like any other units. First, decide the units of the desired answer. Suppose you want to find out how much time you spend shopping per month. The desired units are hours per month. Suppose you spend an average of three hours per day shopping on both Saturday and Sunday — a real shop-until-you-drop shopper! (See equation 1-7.)

$$\frac{3+3 \text{ hours}}{1 \text{ week}} \times \frac{4.3 \text{ weeks}}{1 \text{ month}} = 26 \text{ hours per month (Equation 1-7)}$$

In dimensional analysis, the information from the problem is written down before doing any calculations. The first ratio of equation 1-7 adds three hours on Saturday to the three hours on Sunday and divides these shopping hours by a week. This first ratio gives the number of shopping hours per week. The first ratio (hours per week) is not in the desired units of hours per month.

The number of weeks per month actually changes from month to month. Most months have four weekends, but some have five weekends. Here we can use a conversion factor that is only approximately true. There are about 4.3 weeks in an average month. Multiplying the first ratio by this crude conversion factor and canceling "weeks," a number of around 26 hours per month is found.

If you check the number on a calculator, you will find that 26 is not exactly what it will compute. The calculator number should be rounded because the extra digits do not mean much. The conversion factor of 4.3 weeks per month only has two digits that are close to being accurate. These meaningful digits are called "significant figures." The answer should be no more precise than the least precise number in the problem. Therefore, the answer should have only two digits (the 2 and the 6).

## The money value of time

Time is not money, but everybody is willing to trade one for the other. If you give someone money in exchange for time, you are a customer or a boss. If you spend time doing things for money, you are an employee or a business owner.

Knowing roughly how much your time is worth can help. If you are paid \$10 per hour at your job, perhaps time spent on things you enjoy also costs \$10 per hour. You may charge a different rate for things you do not enjoy — such as \$15 per hour. Also, you may charge a different rate depending on the time of day. Many people are most alert early in the day. These people may charge two to five times as much for this time as for time right after lunch.

Perhaps buying a new shirt costs \$18 dollars. A smart shopper knows that the purchase price (including tax) is only part of the shirt's cost. It also costs money to shop for the shirt and, later, to take care of it. For people whose time is very valuable, the shopping time can cost more than the shirt. If Demi Moore can earn \$200 per hour through her acting (it may be more for her) and it takes her five minutes to pick out and buy a shirt, the shirt becomes expensive. (See equation 1-8.)

$$5 \text{ minutes} \times \frac{1 \text{ hour}}{60 \text{ minutes}} \times \frac{\$200}{1 \text{ hour}} = \$20 \text{ for the time} \quad \text{(Equation 1-8)}$$

In equation 1-8, time is converted from minutes into hours and the hours are converted into money equivalents. Note that the result is only approximately $20 because the shopping time is only approximately five minutes, and the time is only approximately worth $200 per hour. The price of the shirt goes up from $18 to about $40 because of the time it takes away from rehearsing love scenes.

## Time-saving tips

(For some people who are new to the ways of time management but are eager to learn, this one section could repay the cost of this book.)

The surest and best way to improve your use of time is to apply the scientific method to the problem.

As always, the method starts with a goal. Many people have modest goals for time management. The goals are sometimes as simple as finishing the chores early to watch more TV or getting more things done in an eight-hour workday. Other people with more ambition or greater responsibility begin with a plan of what they want to do with their life. The life plan is very helpful in deciding which tasks are important. A task that helps fulfill a life's dream is important. A plan is useful because even trivial tasks can become urgent. Meeting a deadline can be either urgent and important or simply urgent.

The next part of the scientific method is collecting data. After the goal is selected but before making any changes to save time, keep a record of how you spend time for a few days. To reduce the paperwork, a form called a time log should be created before collecting data. Every fifteen minutes just make one check on the time log to show how the last fifteen minutes were spent. A time log should be tried only two to four times per year because keeping records can become a time waster.

## Simple Time Log

| | Sleep | Meals | Work | School | Play | TV | Driving |
|---|---|---|---|---|---|---|---|
| 8 AM - 8:15 AM | | X | | | | | |
| 8:15 AM - 8:30 AM | | | | | | | X |
| 8:30 AM - 8:45 AM | | | | | | | X |
| 8:45 AM - 9 AM | | | X | | | | |
| 9 AM - 9:15 AM | | | X | | | | |
| 9:15 AM - 9:30 AM | | | X | | | | |
| 9:30 AM - 9:45 AM | | | X | | | | |
| 9:45 AM - 10 AM | | | X | | | | |
| 10 AM - 10:15 AM | | | X | | | | |
| 10:15 AM - 10:30 AM | | | X | | | | |
| 10:30 AM - 10:45 AM | | | X | | | | |
| 10:45 AM - 11 AM | | | X | | | | |
| 11 AM - 11:15 AM | | | X | | | | |
| 11:15 AM - 11:30 AM | | | X | | | | |
| 11:30 AM - 11:45 AM | | X | | | | | |
| 11:45 AM - 12 Noon | | X | | | | | |
| 12 Noon - 12:15 PM | | | | X | | | |
| 12:15 PM - 12:30 PM | | | | X | | | |
| 12:30 PM - 12:45 PM | | | | X | | | |
| 12:45 PM - 1 PM | | | | X | | | |
| 1 PM - 1:15 PM | | | | X | | | |
| 1:15 PM - 1:30 PM | | | | X | | | |
| 1:30 PM - 1:45 PM | X | | | | | | |
| 1:45 PM - 2 PM | X | | | | | | |
| 2 PM - 2:15 PM | | | | | X | | |
| 2:15 PM - 2:30 PM | | | | | X | | |
| 2:30 PM - 2:45 PM | | | | | | | X |
| 2:45 PM - 3 PM | | | | | | | X |
| 3 PM - 3:15 PM | | | | | | X | |
| 3:15 PM - 3:30 PM | | | | | | X | |
| 3:30 PM - 3:45 PM | | | | | | X | |
| 3:45 PM - 4 PM | | | | | | X | |
| 4 PM - 4:15 PM | | | | | | X | |
| 4:15 PM - 4:30 PM | | | | | | X | |
| 4:30 PM - 4:45 PM | | | X | | | | |
| 4:45 PM - 5 PM | | | X | | | | |
| 5 PM - 5:15 PM | | | | | | X | |
| 5:15 PM - 5:30 PM | | | | | | X | |

After the time logs for several days are completed, the next step in the method is to look for patterns in the data. Perhaps an average of two hours per day is spent watching TV. Perhaps most of the work time is spent in the mid-afternoon. It is important to find as many patterns as possible.

After patterns are found, you must form hypotheses as to what changes in how time is spent will bring you closer to your goal. The areas of the least importance that cost the most time are usually the best targets for improvement.

Once the target areas are identified, various ways can be tried to reduce wasted time. These methods include:

1) Avoiding the time-wasting activity completely. For example, many people with full lives can reduce the amount of time spent watching TV. Real people are often more amusing.

2) Avoiding travel by using the telephone or other electronics. Driving costs about 25 cents and two minutes per mile. A call almost always costs less and lets you speak to the person with far less waiting. Calling ahead lets the people at your destination know that you are coming. It also lets you know if there has been a change in plans.

3) Putting things in their proper locations. This makes it easy to quickly find important papers and tools.

4) Developing habits or routines. Practicing and improving the way a task is performed can reduce the time required to do it. Touch typists have used this method to type many words per minute. Any task that is done often can be practiced until it takes less time. Trying to reduce wasted motion usually helps.

5) Automating routine tasks. Any task such as filing data, writing, or number crunching can be done in less time with a computer — after you learn how to use it. Other time-saving devices include the microwave oven, food processors, dishwashers, etc. The more time an activity takes per week; the more likely it is that automation will save time.

6) Doing two or more things at the same time. In a chemistry lab, there are devices that will stir and heat chemical reactions while the chemist is reading a book. A chemist might have several reactions going at the same time. Likewise, a homemaker can look after the kids while cooking two types of food in the oven, washing the dishes, drying the clothes, and vacuuming the rug. In this way, one person can do the work that used to take many hours or a couple of servants to do.

Note: The scientific method of gathering facts, searching for patterns, forming theories, and using the new knowledge can also help save

money. First, select a financial goal. Next, keep careful records on how your money is spent. Finally, try various ways to save money to see if they help.

## Some Dimensional Analysis Problems

The only way to learn a new mathematical tool is to work some problems that require it. This section provides some practice in the fine art of using dimensional analysis. The answers can be found in Appendix A near the back of the book.

### Problem 1.1

Baked goods are commonly discounted if they are not sold immediately. Whole shelves of perfectly edible pastries are often for sale at a deep discount. One example is a box of pastries weighing 24 ounces for sale at a price of $1.56. In the same store, the price of another brand of pastry was $3.49 for one pound. To properly compare numbers, the units of the numbers must be the same. Convert both prices to dollars per ounce. Which type of pastry was more expensive?

### Problem 1.2

Many people do not like waiting even though their time is worth much less than Demi Moore's. A five-minute wait at a fast-food restaurant can upset some people. Assume that their employer pays them $10 per hour. Also assume that waiting around at lunch time is unpleasant and should be charged $15 per hour instead of what they get at work. How much did that five-minute wait cost them?

### Problem 1.3

Driving is an activity rich in ways of practicing penny wisdom. With a cost of around 25 cents per mile and many people driving thousands of miles per year, the chance to save a mile happens very often. A common choice facing many drivers is whether to use a highway or to take a short cut using back roads.

Suppose that both the highway and the short cut have two stop signs. This means that losses from stopping and starting are the same for both routes. The highway has a distance of 10 miles and a speed limit of 65 miles per hour. The short cut has a distance of 7 miles and a speed limit of 45 miles per hour.

How much money is saved by using the short cut? How much is the gain or loss of time with the shortcut? How much is the saved time worth if your driving time is worth $10 per hour?

# Chapter 2

# The Matter of Sleep

## Sleep? In a Chemistry Book?

Besides the fact that many people sleep during chemistry lectures, sleep is a natural part of the science of chemistry. Many foods and drugs can affect sleep for better or worse. Also, the subject of sleep is mostly about the human body's chemical systems. The biochemistry of sleep is why it belongs in this book.

This chapter will show you how to use both chemical and non-chemical means to get more out of your waking and sleeping hours. As in other areas of health, many people hope for a wonder drug. Those who grew up with aspirin and antibiotics tend to expect every cure to come in a little bottle with warning labels on it. In this case, things are not so simple.

Humans must sleep or face serious health problems. Except in a few life-threatening situations, the best anybody can do is to sleep soundly and be alert for a fraction of their waking hours.

## The Functions of Sleep

Sleeping may serve more than one purpose. Researchers have found that human sleep goes through several stages. These stages are marked by different electrical patterns in the brain and different muscle movements. The purpose of each stage is not well understood, but the fact that sleep changes through the night suggests that it helps the body in more than one way.

Many people think that sleep helps the body repair itself. Sleep may also be an instinct to conserve energy or to keep the body out of

trouble. Certainly, mothers are often glad when their children are asleep and require less attention. These mothers might support the "keeping out of trouble" instinct theory.

### Rest

Quietly lying still is not a substitute for sleeping. Rest can help repair most body tissue, but it cannot repair certain parts of the brain that are active when a person is awake. It is similar to trying to fix an engine while it is running. Long periods of quiet, sleepless rest result in increasingly poor scores on mental tests.

## An Introduction to the EEG

One of the most useful units of sleep may surprise you. While time is the most useful unit of sleep, the second most useful unit is the volt. A volt is a unit of electrical potential that describes how much energy can be obtained by running a wire from one place to another. In the case of sleep, the wires are connected to the outside of a head. The ends of the wires are called electrodes — like the ends of batteries.

These electrodes can pick up the tiny electrical changes resulting from brain activity. This does not mean that scientists can read minds, yet. However, these changes in voltage can show how deeply asleep a person is and what type of sleep the subject is in.

The electrodes are placed outside the part of the brain called the cerebral cortex (also called the encephalon). This method of measuring voltage changes inside the encephalon is called electroencephalography (EEG) and the printout is called an electroencephalogram. Sleep researchers tend to call everything an "EEG." The machine, the technique, the printout, and related animal studies are all called "EEG."

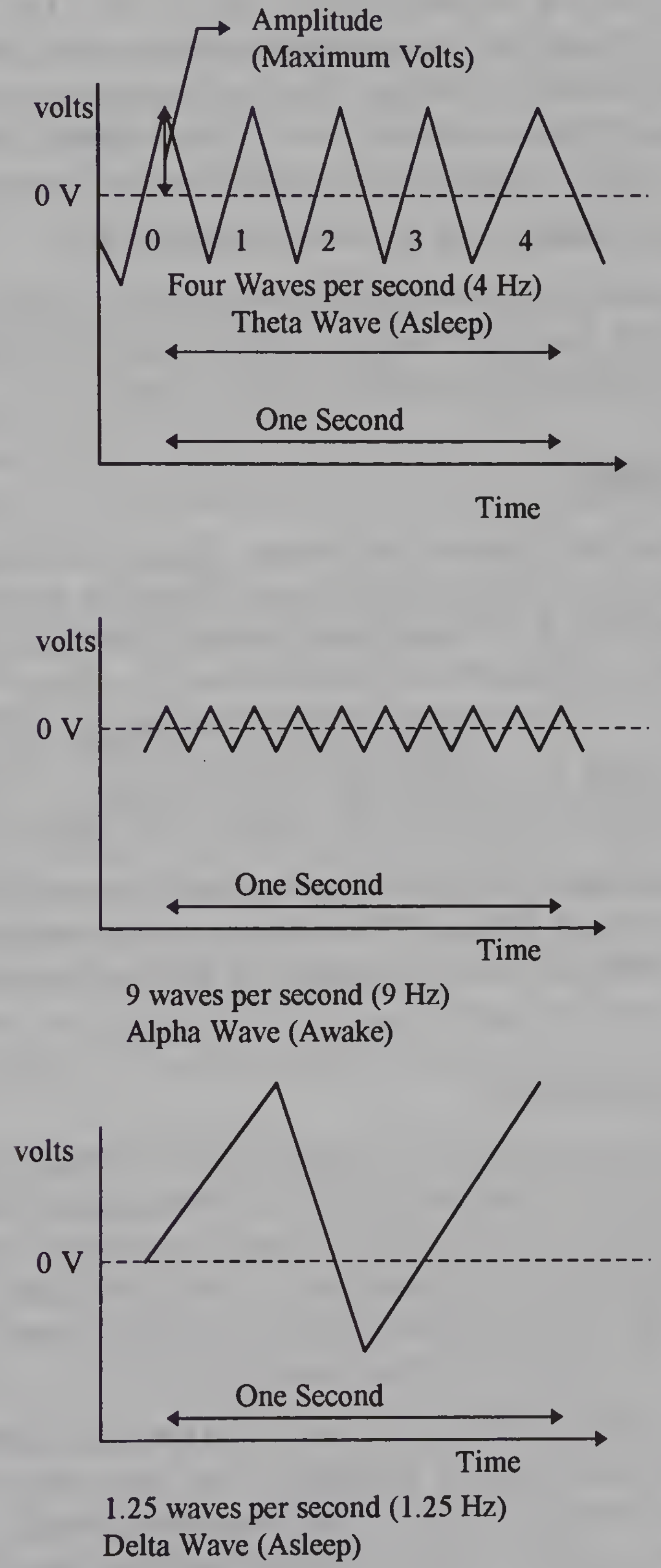
At this point, chemistry makes a little but valuable contribution. The electrodes have to be placed on the head for several hours and then removed. This calls for a special glue that holds tightly to skin, causes no big reaction, and washes off easily at the end of the session. Chemists have created glues that hold tight until an organic solvent washes them away (like super glues).

### Interpreting the output of the EEG

The electroencephalogram can be interpreted like any sort of wave (although surf boarding is not possible on these waves!). Waves are known for their frequency (how many waves happen in a second or minute)

and their amplitude (how big the wave is). For the EEG, a big amplitude is measured in the hundreds of millionths of a volt (more than 100 microvolts).

**Simplified Brain Waves**



A hertz, Hz, is a wave per second. A wave that goes up and down five times in a second has a frequency of 5 hertz. Typical waves found in people who are awake include alpha waves with a frequency of 8 to 11 Hz and beta waves with a frequency higher than 15 Hz. The sleeping waves are theta (3.5-7.5 Hz) and delta (lower frequency than 3.5 Hz and often over 100 microvolts in amplitude). Just by looking at the pattern of the waves from the EEG, it is possible to tell if the subject is really asleep or just faking it. A little version of this would be handy for baby-sitting!

### Electrodes for measuring muscle movements

Researchers also place electrodes near the eyes and on the neck to detect the muscle spasms. Changes in these muscles help to determine whether the subject is in light sleep or "REM" sleep.

## Stages of Sleep

Sleep has been broken into stages. Stage 0 is the state of being awake. Stage 1 is drowsiness or light sleep. Stage 2 is a mixture of waves. Stage 3 is a transition to the deep stage 4 sleep. Stage 4 is made up of low frequency, high-amplitude waves called delta waves. Stage 4 is called slow wave sleep (SWS). These categories help in the analysis of EEG outputs.

REM (rapid eye movement) sleep is stage 1 with rapid eye movements, extreme relaxation of the muscles in the neck, and dreaming.

Of these stages, the most important seem to be SWS and REM sleep. Deprivation of either of these stages causes problems. Stage 2 sleeping that makes up a large portion of the night seems to be less important.

### When the stages occur

In the first four hours of a normal night's sleep, a person quickly drops down to SWS, comes back up to light sleep, and goes back to stage 4 again. Researchers who attach great value to slow wave sleep use this to say that the first four hours of sleep are the most important. The last four hours are typically stage 2 (regular sleep) and REM sleep. Also, many people briefly wake up once or twice during a night.

Half of a night's deepest sleep occurs in the first 90 minutes. In the next 90 minutes about 25% of the night's total deep sleep occurs. With every following 90-minute cycle, people spend less time in stage 4 sleep and more time in light sleep. Constant halving like this is called

"exponential decay" and is common throughout nature. Radioactive materials also decay like this with half of the material changing form every so often. The half-life of SWS is about 90 minutes.

### REM sleep

Rapid eye movements (REM) characterize light sleep when dreams occur. (This is not to be confused with the rock band from Athens, Georgia.) Many sleep researchers are very interested in this type of sleep, and REM sleep seems to be important for humans. This type of sleep seems to take more time in humans than in other mammals.

A number of theories about REM sleep are popular. Some theories say that it helps manage the memories of the past day's events — either by forgetting the useless parts or remembering the useful events. Other theories suggest that it is safer than other forms of sleep because the sleeper is better able to react to things such as loud noises. Still other theories suggest that emotions are controlled during REM sleep.

Whatever its purpose, REM sleep seems to be required by the body. After going without sleep for longer than usual, the body tries to make up about half of the lost REM sleep.

## Skimping on Sleep (Occasionally)

At least one sleep researcher has suggested that sleep gets its most important work finished first. If the body can get most of the important work done in the first six hours (four 90-minute cycles), the last two hours (one or two cycles) are not as critical. If the theory is true, it suggests that occasionally skimping a little on sleep is possible. Shortening the sleeping time by a few hours seems to be much healthier than skipping sleep entirely. However, several days of short nighttime sleep can reduce alertness.

When some well-meaning person suggests that you should sleep less, remember Parkinson's law. This law states that the time needed to complete a task expands to fill the time available. In other words, the more time a person has to do a job; the longer the job will take. A study that involved cutting back on sleep confirmed Parkinson's law. The subjects just wasted the extra time. Using the extra time wisely can be difficult.

One often hears about catching up on missed sleep. The body actually does catch up on the deepest type of sleep (SWS), and to a lesser extent, REM sleep. While the body is making up a loss of sleep, more sleeping time is spent in SWS and REM sleep. However, the total time

asleep is only slightly longer than usual. Light sleep of stages 1 and 2 are simply lost.

## The Chemicals of Slow Wave Sleep

There is increased secretion of growth hormone in SWS which supports the theory that sleep is used to repair wear and tear on the body. A hormone is a chemical made by a gland such as the brain's pituitary gland. Hormones control the body's functions. Growth hormone seems to promote the growth of new tissue that can be used to replace old tissue or increase height and weight.

A chemical known as interleukin-1 can also increase deep sleep. The human body uses this material to promote fevers and to help the immune system. Because this chemical both promotes sleep and helps the immune system, it seems that sleep helps fight off diseases. This may be why it is easier to sleep after a fever (unless sneezing and coughing keeps you awake).

## The Cause of Sleep — a Sleep Substance?

Natural materials that cause sleep have been found in the body. However, none of them builds up from the time of waking until sleep begins and then drops to a very low level at the end of sleep. If a chemical like this can be found, it would probably be the sleep chemical. Perhaps scientists could find an antidote to sleep, and Mr. Sandman would have to find a new job.

### The biological clock

Humans have a biological clock that gives the body a daily cycle of temperature called a "circadian rhythm." The clock is actually a tiny bit of brain tissue that keeps track of time for the person.

The biological clock tends to run a little slow — closer to 25 hours rather than 24 hours. Sunlight in the early morning resets it back an hour to match real time.

The biological clock does not directly control the sleep cycle. Sleep is less tightly controlled by the body. In a laboratory it is possible to change the sleep cycle from 25 hours to 30, 40, 50, or more hours.

However, sleep normally occurs when the biological clock lowers the body's temperature. When body temperature is at its lowest, the person is usually most sleepy and least alert. For people who regularly

sleep between 11 PM and 7 AM, the lowest body temperature comes between 3 AM and 6 AM whether they are asleep or not. The biological clock starts warming the body about an hour before the usual waking time, so the brain will be warm and ready to go upon waking.

| **Time** | **Alertness** |
|---|---|
| 7 AM - 9 AM | Alert |
| 9 AM - 10 AM | Very Alert |
| 10 AM - 1:30 PM | Alert |
| 1:30 PM - 3 PM | Sleepy ("Siesta") |
| 3 PM - 4:30 PM | Alert |
| 4:30 PM - 9 PM | Very Alert |
| 9 PM - 11 PM | Alert |
| 11 PM - 3 AM | Sleepy |
| 3 AM - 6 AM | Very Sleepy |
| 6 AM - 7 AM | Sleepy |

Table 2-1: A Typical Biological Clock (for someone who wakes at 7 AM)

In the absence of bright light, this clock shifts forward an hour every day. In a cave, the waking time would shift from 7 AM to 8 AM on the first day and then to 9 AM on the second day. Bedtimes tend to become later and later as well. Most people avoid this problem by letting sunlight into their bedroom. This bright light shifts their biological clock back an hour and makes it easier to wake up again at 7 AM twenty-four hours later.

Suppose that your alarm clock helps you wake up at 6 AM instead of your usual 7 AM. You will probably be groggy because your body temperature will not have fully warmed yet. If you stumble to the window and let the light into your eyes (assuming it is bright outside), it will not help you much on that day, but it will make it easier to wake up at 6 AM on the following morning.

Note: Looking directly into the sun is not necessary and can damage the back of the eye. Looking at a brightly lit cloud or tree provides plenty of light to reset the biological clock.

Besides shifting the clock backwards to maintain a regular sleep schedule, light can also shift it forward. When light hits the back of the human eye, the optic nerve sends messages to various parts of the brain. The biological clock is sensitive to light when it expects it to be dark outside. Although the clock does not respond to light during the day, a bright light in the night can change the time setting. If you stay up late and are exposed to bright lights, it becomes easier to stay in bed late into the morning (or afternoon!) and to stay up late the next night.

To reset the biological clock, it is necessary to see brighter lights than the typical office lighting. A brightly lit office is often much darker than a heavily overcast day. A light source that some people use is a visor that simulates a bright day. This is a common treatment for seasonal affective disorder (SAD). Light is also the best medicine for curing such clock problems as jet lag or daylight-saving time. Of course, chemists and doctors are trying to find some expensive cures.

### Clock resetting with melatonin

Melatonin is a hormone produced by the pineal gland (of the brain — in case you were wondering). The body produces this hormone at night and it seems to help reset the biological clock. It shows promise as a treatment for jet lag. Again, the best cure currently known is seeing bright lights at the right times. Other widely promoted cures for jet lag reduce the loss of sleep that is one of the symptoms of jet lag.

### Serotonin — a sleep promoter

Serotonin is a type of neurotransmitter that seems to promote sleep. Neurotransmitters are chemicals that help nerves send messages. While some of these messages can excite, serotonin in the brain tends to calm humans.

Serotonin is made (synthesized) from the amino acid L-tryptophan. The synthesis also needs help from vitamin $B_6$. Most animals and all humans obtain amino acids from eating many types of protein. However, eating or drinking a meal rich in protein does not always promote sleep. Sometimes, serotonin levels can actually fall after a meal because other amino acids from protein may compete with L-tryptophan. The other proteins in a protein-rich meal may help produce some of the body's stimulants such as noradrenalin. Even eating L-tryptophan pills may not help in some cases because the body can burn excess proteins and amino acids.

Strangely, one way to increase a human body's serotonin level is to eat a meal rich in carbohydrates such as sugars and starches. The increased level of insulin in the blood needed to digest these foods releases L-tryptophan. Sleepiness can result after the meal. (Note: Sleepiness occurs during the siesta (about 1:30 PM to 3 PM for people who wake at 7 AM) whether or not a meal is eaten, but eating a meal can increase the sleepiness.)

The human body often has excess L-tryptophan floating around. Thus, another approach is increasing the blood levels of vitamin $B_6$ by taking a supplement. Sometimes this works so well at increasing serotonin levels that the person can become drowsy at the wrong time.

For some people, all of these attempts to increase serotonin levels will be futile. Enzymes are biological chemicals that make chemical reactions happen. There are enzymes in everyone to destroy excess serotonin. No matter how much milk, meat, candy, L-tryptophan, or vitamin $B_6$ some people consume; any increase in serotonin will be destroyed by these enzymes.

If the body did not have these enzymes, all the serotonin that the body naturally produces would build up. People would become sleepier and sleepier until they would fall into a coma. Fortunately, most people have good control over the level of chemicals in their bodies and this is rarely a problem.

## Sleep Problems

Most people suffer from sleep problems of some sort at least once in their lifetime. Some of the more common problems are given below.

### Insomnia

Insomnia is difficulty in getting a full night's rest. One-third of the people in the United States suffer from it to some extent, and one out of eight sometimes resort to sleeping pills. A study done back in the late 1970s found that sleeping pills made it easier to fall asleep but extended sleep by only 30 minutes or so. Many of the pills worked by reducing anxiety. People thought they had a better night's sleep because they did not worry as much during the night.

Unfortunately, sleeping pills usually cannot provide long-term relief for sleep problems. Such non-chemical practices as cutting out naps, keeping a regular schedule (including weekends and holidays), only going to bed when sleepy, and getting out of bed if unable to sleep are often

better long-run treatments for insomnia. A bed should be associated with sleep and not with lying in bed awake. A bed should only be used when so tired that sleep comes quickly. (Of course you and your spouse may find one or two other things to do on it.)

### Problems with rotating shifts

One cause of insomnia is changing shifts at work. However, other problems may also result from shift work. Digestive problems such as hunger pangs at unusual times or ulcers are more common for those on rotating shifts. These problems are the result of the body preparing to eat by releasing digestive enzymes, but finding no food in the stomach. Eating food before the body is prepared to digest it can be just as bad.

Workers placed on rotating shifts often find increases in their blood levels of lipids such as fats and cholesterol. Heart problems can result from these extra lipids.

Illnesses such as diabetes or epilepsy can be difficult to control on rotating shifts. An irregular schedule can make it hard to regularly take medicine.

Some people are more suited to rotating shift work than others. Those who can quickly adjust to new shifts with a little loss of sleep may take advantage of the higher pay of shift work. They should be aware that as a body grows older it may become more rigid in its sleep habits. If changes in shifts begin to cause sleeping troubles, finding a new job could avoid a lot of health problems.

### Jet lag

The body temperature clock takes a while to adjust to changes in time zone — sometimes longer than two weeks. The problem is worse when traveling eastward and losing hours. While the clock is adjusting, sleepiness, headaches, and loss of appetite can result. Throwing up in the lap of the Prime Minister of Japan and then collapsing under a table would be bad. Even worse would be falling asleep while driving.

### The siesta

In the early afternoon, it becomes very easy to take a nap. This can make some tasks much more difficult. Anything that requires careful attention should be avoided during the siesta. It is no coincidence that there is an increase in traffic accidents in the hours right after lunch.

Creative people such as writers or artists will not get any work done while they are sleepy. So, they may as well watch TV during the siesta. In some countries, many people take naps during this time.

### Microsleeps

When a person is very sleepy, an EEG of the subject's brain waves can show brief periods (five to ten seconds each) when the person appears to be awake but is actually asleep. The person has no idea of what is around him or her at that time. This is a great time to watch TV because, at worst, you could miss the winning play in the Super Bowl. An even better idea is to watch videotapes. The best idea is to get some sleep.

## Sleep Medication Strategies

Drugs, such as caffeine or alcohol, are rarely the best solution to alertness or sleeping problems. While they have valid uses, daily intake of these materials can create new problems. Since we are a nation of coffee and beer drinkers, it would be silly to overstate the problems of these adult beverages. Still, if you find yourself becoming too tense, try cutting down on your coffee before trying yoga or Valium. If abused, alcohol can also cause some nasty problems.

### Hypnotics and sedatives

Hypnotics promote sleep. Sedatives promote peace and quiet. Either type of drug can induce sleep at bedtime.

Many drugs like these can be dangerous and require a prescription. One reason for this is that they interact in harmful ways with other drugs such as alcohol or antihistamines. Interactions with other drugs can magnify the effect of the sedative — sometimes producing a coma or death. Another reason is that some of these drugs, such as barbiturates, are habit forming and may cause physical or mental problems.

Most types of sleeping pills require a doctor's prescription, and he or she can explain all the side effects. The important point is that treatments for lack of sleep are available, but they can be misused. (Just ask Elvis.)

(A special note for movie buffs: Chloral hydrate is the dreaded "Mickey Finn." It is a powder used in some movies to put the main character to sleep. It quickly dissolves in alcohol-rich drinks to cause unsuspecting drinkers to sleep for five to eight hours. It is used in movies

almost as often as dry ice, but unlike real life, the characters rarely wake up to fits of vomiting.)

### Alcohol

The common type of alcohol (grain alcohol), found in such drinks as beer or wine, was once used as a medicine in several ways. “Good for what ails yer, partner!” might be heard in an old Western. Back then, the doctors had few medicines to choose among. Alcohol often had to serve as a local antiseptic (kills germs on contact), an astringent (stops bleeding of minor wounds), an agent to improve appetite and digestion, or a hypnotic (promotes sleep) — depending on the situation.

Alcohol often produces feelings of well-being and wanting to talk. In large amounts, the senses become dulled and the person usually talks louder because he or she cannot hear normally.

Alcohol can promote sleep in some people some of the time. After drinking alcohol, some people find it easier to fall asleep (or pass out). The dulling of the senses can make pain more bearable and less likely to keep a person awake. Most hypnotics do not work for people in pain the way alcohol can.

However, it is not good to rely on alcohol to fall asleep because it can result in addiction and a variety of health problems. The liver can be damaged by digesting alcohol on a regular basis. Some people die because of alcohol-induced liver failure. Mickey Mantle’s liver problems were made worse because of his past drinking habits. Also, many drugs will interact with alcohol to cause sickness or death. Never take alcohol and barbiturates at the same time!

### Caffeine

Pure caffeine is a solid that forms crystals. Most people will never see the pure crystals, but consume it in their coffee or soft drinks as a watery solution. Some people also take alertness pills made from caffeine extracted from coffee beans.

Caffeine will dissolve in water or alcohol. This chemical property is used to form such aqueous solutions as coffee, tea, and many types of soda pop. A major reason why it is found in those drinks is that caffeine mildly stimulates the brain. This makes caffeine a central nervous system stimulant. Caffeine also stimulates breathing and makes urination (going to pee) more frequent. Other side effects include rapid heart beats and irritability caused by lack of sleep.

Caffeine from any source can postpone sleep. In the United States, coffee is the most common source of caffeine. It is so common that non-coffee drinkers often have to explain why they do not drink coffee. Depending on the strength of the coffee, the concentration of caffeine is anywhere from 60 to 200 milligrams (mg) per cup. (One hundred milligrams is less than 1/100th of an ounce — not many crystals at all.) Most soft drinks that contain caffeine have about 35 to 55 mg per 12-ounce can.

Tea has 30 to 50 mg per cup. A tea drinker may find it more stimulating than these numbers suggest because tea contains a second stimulant called "theophylline." Cocoa has around 5 mg of caffeine per cup, but it is rich in the stimulant called "theobromine." (It turns out that the material called "bromine" is not directly related to theobromine.) Chocolate is also made from cocoa beans and has about 6 mg of caffeine per ounce.

### A strategy for taking caffeine

Coffee has more effect on some people than others because some caffeine users build up a tolerance. People with a tolerance for caffeine must consume more of it to become alert.

Someone with no tolerance for caffeine needs 0.7 mg per pound of body weight to have his or her sleep postponed. Suppose you weigh 150 pounds. Will one cup of normal strength coffee (about 100 mg per cup) be enough to keep you awake? (See equation 2-1.)

$$\frac{1 \text{ cup}}{150 \text{ lbs of body weight}} \times \frac{100 \text{ mg}}{1 \text{ cup}} = 0.67 \text{ mg per lb of body} \quad \text{(Equation 2-1)}$$

The equation above takes the given information of one cup per 150 pounds and converts the cup of coffee into milligrams of caffeine. The answer is not conclusive. The coffee may or may not keep you awake, but a second cup will do so if you have not built up a tolerance.

Caffeine may take several hours to wash out of the body's system. After drinking lots of coffee to stay awake at work, it may be hard to fall asleep with the caffeine still working. Avoiding caffeine several hours before sleep should help.

Be careful with stimulants such as caffeine because they can become addictive and interfere with normal sleep patterns.

## Maximizing Alertness and Productivity

The problem with most time management systems is that they assume that one minute in the morning is the same as one minute in the afternoon. If the person is very alert in the morning but sleepy during the afternoon siesta, that minute in the morning is far more valuable. The suggestions below use the body's chemistry to make working (or playing) time more productive.

### Finding peak times

Finding and wisely using the body's peak times can more than double the output of creative work possible in a day. Finding those times when the brain is most alert requires staying on a regular schedule for several weeks. You must wake up at the same time every morning and go to sleep at the same time every night. Also, you must find a creative activity to test when you are at your best. Examples would be drawing sketches, playing a computer game, or writing.

Over the weeks on a regular schedule, keep track of how creative you are at different times of the day. Most people will have a pattern similar to a typical biological clock with peak times in the early morning and early evening hours. Your times may differ from the average times. (Note that this is just an application of the scientific method from the first chapter.)

You may decide that you like being on a regular schedule. A regular schedule with enough sleep can provide sleepiness at bedtime, predictable times when work is most productive, and better health. Also, a regular schedule can reduce the grogginess from waking from a deep sleep (stage 4). A regular waking time lets the brain warm up prior to waking.

### Using peak times for problem solving

A possible use for knowing your peak times is finding out if a difficult problem can be solved, or whether it requires more time and effort. The basic approach is to wait until you are in a peak time and then give the problem a try. If you cannot make progress on it, you are missing some data or lack some skill needed to solve the problem. However, there is a subtle biochemical aspect to this problem-solving trick.

. A sleeping person goes through 90 to 100-minute cycles of deep sleep and lighter sleep. While these 90-minute cycles are much more pronounced at night, this effect, called the basic rest activity cycle, is

noticeable even during the day. Even at a peak time, there is a 90-minute cycle of moderate alertness to extreme alertness.

The times of extreme alertness are hard to predict even for those on a fairly regular schedule. A practical approach is to wait until a peak time and then give the problem a try. If you can quickly see a good way to solve it, you have your answer. If you are stumped, set the problem aside for a few minutes. It may be that you were at a low point in the basic rest activity cycle.

Try to solve the problem several times over 90 minutes. If you are still clueless, further work on it would be futile. In that case, it is best to work on something else. Developing new skills or finding new information is a better use of time and may result in a new way of looking at the problem.

### Using the siesta as an opportunity

Most employers in the United States simply do not understand that people get tired during their siesta. For example, they often schedule meetings during this time and are shocked to see some key people fall asleep.

Still, the siesta is not all bad — if you can control your working hours. By taking a nap at that time, you can stay awake late into the evening while remaining alert. This added flexibility to a regular schedule can be handy from time to time.

## Factors that Promote Drowsiness or Alertness

### Interest in the situation

Motivation is one of the factors that can increase alertness. New or exciting situations can trigger chemicals in the body to increase heart rate and shake off drowsiness. Most people, for example, find it hard to fall asleep right after nearly losing their life.

Interest depends somewhat on the person. A game of chess is likely to keep an avid player awake, but not most spectators.

### Muscular activity

Any sort of muscular activity helps to keep you awake. Vigorous activities such as jogging can keep someone awake for more than an hour after the activity is finished. Even chewing gum can keep you awake.

Taking notes or doodling can help get you through a boring meeting or class.

### Time on the circadian clock

For those people who wake at 7 AM, the hours of 1:30 PM to 3:00 PM (siesta) and 11 PM to 7 AM (nighttime sleep) tend to be periods of low alertness. The hours of 9 AM to 10 AM and 4:30 PM to 9 PM tend to be periods of peak alertness. Your body may have a different pattern. Check just to be sure.

If your schedule changes, the peak hours will change as well. For example, if you wake at 4 AM, just subtract 3 hours from the 7 AM hours above. The peak time of 9 AM to 10 AM becomes 6 AM to 7 AM.

### Sleep bank balance

The body keeps track of hours slept and the quality of the sleep — like a banker keeps track of a checking account balance. When a person remains awake longer than a typical 16 hours in a row, sleep is taken out of the sleep bank and he or she becomes drowsy. Short-night sleeps require full-night sleeps in the future to repay the sleep bank.

The body does not demand exactly 40 hours of sleep over five days. Rather, it requires an extra hour or two of sleep on the weekend to make up for losing sleep during the week. Naps during the day are very effective at adding sleep to sleep bank balance.

### Ingested nutrients and chemicals

Alertness can be affected by chemicals smelled, eaten, or absorbed through the skin. Hypnotics and sedatives, such as alcohol, promote sleep. Stimulants, such as caffeine, promote alertness. While chemicals can sometimes be useful, they can easily be abused.

### Light

Bright lights can increase alertness and reset the biological clock. Many employers know that bright lights make workers more alert. For that reason, most companies keep the lights brightly lit for the night shift. Employers with dim lights quickly discover that their workers become drowsy. Unfortunately, both truckers and pilots have to sit in dark cabins at night.

### Temperature and humidity

Cool the face and alertness is increased. Those who want to stay awake often find that cold water on the face wakes them up.

Warm and humid conditions bring on sleepiness. It may be that the heat speeds up chemical reactions in the brain and makes sleep more necessary to repair it. If you happen to be physically fit and can vigorously exercise for at least 30 minutes, you may find that you sleep better. Exercise builds up lots of heat as a by-product of doing physical work. This heat warms the brain and makes sleep sounder.

If you are like most people, you can exercise for hours and not find that your sleep has improved. Most people tire too easily to develop the sleep-enhancing heat. For people who are out of shape, warm water or a sauna can provide the temperature boost. You have to be careful not to overheat, but most people already know to come out when it gets too hot.

### Sound

Sound can either lull us to sleep or keep us awake. "White noise" is a fairly constant sound with no information content, such as the sound of waves rolling into a beach. This type of sound can help induce sleep.

One of the labs that I worked in was beneath a large blower of a ventilation system. Even though the lab was unusually cool, the white noise made it difficult for anyone to stay awake in the room unless they stayed in constant motion. It was almost impossible to read in there for that reason.

Sound can also keep you awake if it is variable. Creaking and bumps in the night can peak interest and increase alertness for that reason. White noise not only helps lull you to sleep; it also drowns out many of the sounds that might keep you awake. On the other hand, a burglar might break into your house and you would never know it!

## Sleep in the Elderly

Elderly people do not sleep like young people. Unbroken sleep at night and going without naps during the day becomes difficult. Sometimes the amount of sleep throughout 24 hours increases and sometimes it decreases. Elderly people often find that taking two or more naps, going to bed late, and waking up early is the most comfortable life-style.

## Special Acknowledgment

I would like to acknowledge Dr. Martin Moore-Ede whose research has heavily influenced this chapter. Any reader interested in the subject of sleep and alertness would be wise to read his book called *The Twenty-Four-Hour Society*. He is an expert in the field and a good writer.

## A Dimensional Analysis Problem

Like the last chapter, this chapter concludes with a dimensional analysis problem. Not only do mathematical tools require work to learn, unless they are used regularly, they are soon forgotten.

Dimensional analysis is very useful for saving time and money. I strongly urge the reader to work the problems in this book and then spend several weeks trying to use dimensional analysis whenever possible. Try to calculate dollars per ounce, miles per gallon, words per day, commercials per hour, and all sorts of other things. Try to put numbers on everything you are interested in. This sort of exercise sharpens your thinking processes.

As for this book, the following problem is the final problem. Its answer can be found in Appendix A.

Coca-Cola Classic has more caffeine than most cola drinks. A 12-ounce can of Coke has a little over 45 milligrams of caffeine. Suppose that a young person weighing 100 pounds is able to drink a full can of Coke and go to sleep without any trouble. Does the child have a tolerance for caffeine?

# Chapter 3

# The Chemistry of Fun

Leisure time is any time not spent working, preparing for work, or sleeping. About 94% of the people in the United States use this time to recover from work, 64% are pleasure seekers, 64% enter contests for fun, and 33% use their free time to further their dreams. Yes, that does not add up to 100%. Some people recover from work by entering contests to further their dreams.

Note that competitiveness and ambition are two different things. Competitive people want to win contests. Ambitious people want to reach goals, even if it does not mean beating anyone. In my opinion, there are not enough ambitious people. Reaching a goal seems more useful than proving that you are better than someone else.

However you use your leisure time, there is something in this chapter for you. If you just recover from work, some chemistry is given for resting, watching TV, and getting a suntan. If you are a pleasure seeker, some chemistry can be found about sports, camping, and looking good (perhaps for dates). Some ways to improve athletic ability may help any competitive readers. If you are ambitious, good for you! The ambitious person will find some useful chemistry that may help further a variety of goals.

## Work and Energy

A good way to begin this chapter is to give the scientific definition of work. After all, how can you tell if you are playing if you do not know what work is? Scientists define "work" as the use of force to move something through a distance. "Fun" is not as well defined.

It is hard for scientists to tell the difference between "fun" work and "work" work. They are not alone in this as more people are working at the things they love best. Work is simply moving things using force — no matter whether it is a log or a chess piece and no matter how much the person is paid to do it.

Work is done on a football every time it is moved against the ball's tendency to stay where it is (called "inertia"). This means that when a quarterback throws a pass he (or she?) is doing work on the ball. Also, every time a defensive lineman sacks a quarterback, it is the tackler who is doing most of the work. It seems to be more fun to work than to be worked upon.

Scientists connect work and energy in a rather intimate way. They say that energy is the ability to do work — whether the energy is in the form of light, heat, chemical, nuclear, electrical, or mechanical energy. A large amount of energy lets a human or a machine do a lot of work. Thus, a quarterback with a lot of energy can throw a lot of passes. A defensive lineman with a lot of energy can sack the quarterback again and again.

Football players use chemical energy to work during a game. To prepare for a game, they eat meals rich in fats, proteins, and carbohydrates. Their bodies convert these foods into chemicals useful for moving their bodies around. They use this stored energy to do such work as running, throwing, tackling, and even thinking. Thinking requires work because chemicals move short distances to transfer thought impulses around the brain.

However, most of the work on the football field will not make the highlights on the news. It takes enormous amounts of energy to push sweat to the surface of the skin, change food into fat, and rebuild damaged tissue. This work is part of the reason why pro-football players are paid so much. They build their bodies and minds to prepare themselves for the game. Throwing the ball or knocking someone over is "fun" because it is the reward for a tremendous amount of work of shaping their bodies to do that.

### The body's energy system

The human body needs energy for contracting muscles every time movement takes place — unless the person is just falling down. (Note that muscles can only contract or relax.) The energy to do this work comes from changing adenosine 5'-triphosphate (ATP) into adenosine 5'-

diphosphate (ADP). Changing ATP into ADP is a common source of quick energy for the human body.

However, a muscle would use up all of the available ATP very quickly. This would make for short foot races! In that first half-second, the muscle contracts with great power. This burst of energy is needed to overcome inertia. It usually takes more energy to start something in motion than to keep it moving.

To keep energy going to the muscles, the body uses another energy source called phosphocreatine. This chemical is found around muscles to supply energy for short periods of less than 10 seconds. The chemical works by converting ADP into ATP with the help of a catalyst (a material that makes the reaction go faster). The ATP goes on to give energy to the muscles. When a muscle contracts, ATP levels drop at first. Next, phosphocreatine levels drop.

Within 10 seconds, the body begins to convert carbohydrates (sugars and starches) into energy. When this process is done without oxygen, it produces less energy than when oxygen is used. (Note that "anaerobic" is a single word that means "without oxygen.") Lactic acid is also formed when energy comes from the anaerobic system. The lactic acid can cause muscle fatigue.

Sports such as arm wrestling or weight lifting can cause a build-up of lactic acid. Even if a weight seems fairly easy to lift, enough pumping iron can cause muscle fatigue. If you are beneath it at the time, a weight might come down and cause damage. Bringing a friend along to act as a spotter and lift the weights when you no longer can, might save a lot of grief.

In the presence of oxygen, muscle cells use their mitochondria to produce energy. A mitochondrion is a little compartment within the cell where a series of chemical reactions converts things such as blood sugar, glycogen, and fat into energy. (Protein is only used when those other fuels are used up.)

The mitochondria convert glucose or glycogen into water and carbon dioxide. At the same time they change a lot of ADP into ATP. This process needs oxygen from the blood and gives the blood carbon dioxide in return. Glycogen and blood sugar burn quickly inside this part of the cell while fat burns more slowly. Fat requires more oxygen to convert it into energy, but stores more energy than glucose or glycogen.

This oxygen-based energy system is called the "aerobic" system. Aerobic means "in the presence of oxygen." Note that putting "an" in front of the word changes its meaning to "without oxygen."

## Physical training

A training program should improve the energy system most needed for the sport. Aerobic capacity usually decides events such as a marathon. The one-mile run is a mixture of different energy systems but anaerobic capacity with its problem of muscle fatigue is often the one that decides the race. Power lifting or short races are mostly decided by speed (the ATP-phosphocreatine system).

You or your trainer must decide what to work on. Endurance sports require work on the aerobic system. Sports with short bursts of speed need work on the other energy systems. Card players and chess players may not need work on any of these energy systems. They may find it more worthwhile to play or study books instead.

Training uses the body's inclination to meet the demands placed on it. Muscles strengthen when they have to work. The body's energy systems also improve with exercise.

## Weight training

Weight training increases the concentrations of ATP, phosphocreatine, and glycogen inside the muscle to provide it with more energy. Fast-twitch muscle fibers also increase in size. The sizes of slow-twitch muscle fibers are not affected by weight training. The fact that some people have more fast-twitch muscle fibers than others explains how some can look like Arnold.

For college-aged men and women, weight training does not change body weight much but decreases the amount of fat. Body weight often increases by a pound or so. Men gain a little over three pounds of muscle and lose about two pounds of fat from all around their bodies (not just where the muscles have become larger). Women lose around three pounds of fat but do not gain as much muscle as men do. Most women have a very hard time increasing the size of their muscles.

A major problem for women who want to become very muscular is that they have little of the hormone that builds muscles. The body uses chemicals called "hormones" to control the life functions of its cells. A hormone called testosterone controls the growth of muscles after weight training. Because women have much less of this hormone than men,

women can exercise all day long and still have smaller muscles than men. The genetics of each person determines what the maximum size of their muscles can be.

Weight training uses a concept called "Le Chatelier's principle" to increase strength in muscles. Le Chatelier's principle says that a system in equilibrium will try to stay in equilibrium. Muscles are in equilibrium when they are strong enough to handle the heaviest loads they are required to lift on a daily basis. If the only heavy load that a person has to carry is a briefcase, the arms of that person are likely to be just strong enough to roll the person out of bed in the morning and carry the briefcase to work.

If the person breaks an arm and it is in a cast for a month, the muscles in the arm will shift to a new equilibrium. When the arm comes out of the cast, it will be difficult to carry the briefcase.

If the same person trains with weights for several months, the arm will become strong because the body tries to build the muscles until they can meet the demands of the environment.

Le Chatelier's principle is actually common to all sciences. Once a system is in equilibrium, it tries to stay in equilibrium. Weight trainers give muscles heavier than usual loads to build muscles until they can handle the new loads. Another application of this principle — this time from physics — is when a young person runs past a priceless vase and brushes against it. If the vase remains in equilibrium, it just wobbles a little before settling down. If it goes out of equilibrium, one child is going to get spanked.

Another example of equilibrium comes from politics. The rulers enact a stupid law. Before the law is passed, the political system is in a stable equilibrium — that is, the people are somewhat satisfied with their leaders. The new law disturbs this equilibrium and causes Le Chatelier's principle to start. Complaints will either cause the law to be repealed (going back to the original equilibrium) or the people will learn to live with the new law (a new equilibrium).

These examples from physics and political science are not the only examples of the equilibrium concept. An equilibrium is any situation that reacts to small changes by going back to "business as usual." Le Chatelier's principle just says that once something is in an equilibrium, it tries hard to stay there. Brush against a vase, and it tries to right itself. Political leaders pass a law, and people try to repeal it. Force a muscle to work hard, and it tries to maintain its ability to lift objects on command.

Almost every mature science has examples of equilibriums. The math that describes equilibria is quite advanced, but the concept is simple and useful.

### Aerobics

If a person rarely walks and never runs, he or she will tire quickly when doing work. Aerobic capacity adjusts to meet the needs of everyday tasks. The body is in equilibrium when it can meet the normal demands placed on it.

Running, swimming or other tasks that increase breathing and heart rates for at least 20 minutes are aerobic. These aerobic exercises can build the body's energy system that burns sugars and fats using oxygen. With a good aerobic system, the body can perform when it matters most — such as in a football game.

During aerobics, a lot of air is consumed. Breathing may increase by a factor of 20. While air is only about 20% oxygen with the rest being mostly nitrogen, this fresh air is richer in oxygen than the human body. The process called "diffusion" moves the oxygen from the lungs into the blood.

The second law of thermodynamics explains the diffusion of oxygen. This law says that the universe always becomes more random. The key to diffusion is that it goes from the lungs where there is a lot of oxygen to the blood where there is less oxygen. The process of diffusion is one that requires no work but goes because it makes the world more random.

Before diffusion, the odds are high that some oxygen can be found quickly in the lungs. After diffusion, oxygen becomes more evenly spread throughout the body and the lungs. The spreading out increases the randomness of the oxygen's location. (Randomness is also called "entropy.") Note how the body uses the laws of nature to supply its need for energy.

While oxygen is diffusing from the air into the bloodstream, carbon dioxide flows from the blood into the lungs. This diffusion removes the carbon dioxide produced by burning stored fuel inside the body. The law of diffusion applies equally to athletes and non-athletes. However, athletes can use oxygen faster than untrained people can.

Athletes increase the size of their lungs with training. The increased surface area of their lungs lets oxygen diffuse more rapidly into

the blood and carbon dioxide leave the blood more quickly. Another factor important in the transportation of oxygen is the quality of the surface of the lungs. Materials that block the surface of the lungs slow the diffusion of oxygen through the lung's tissue. Smokers can build up a coating of tar that can slow the diffusion process.

Smokers often suffer from another more serious problem. Carbon monoxide is produced by burning tobacco. This deadly gas attaches itself to the red blood cells that transport the oxygen to where it is needed in the body. The carbon monoxide crowds out the oxygen and can cause a 10% reduction in the transportation of oxygen. (At higher levels of carbon monoxide, death can result due to lack of oxygen through the body.) To get the most out of their lungs, great athletes tend to be nonsmokers.

Besides increased lung capacity, trained athletes have efficient hearts that can pump more blood. The increased blood flow is needed to transport red blood cells containing oxygen to where the oxygen is used. A trained athlete can increase the speed of blood flow without overworking his or her heart because the volume of blood pushed with each heart beat is greater than that of non-athletes. With the same amount of strain on the heart, trained athletes can push more blood.

To recap, athletes can use more oxygen per breath because of greater lung volume. Also, athletes can push more blood per heart beat because of the larger volume of each stroke of the heart.

Note: Check with your doctor before starting an aerobics program. Exercise increases blood pressure while it is going on. People with high blood pressure can die from too much exercise.

## Rest

Rest is a common goal for leisure. For those who do manual labor, such as construction workers or professional athletes, rest must be part of their leisure time. When the body is doing physical work, it cannot repair itself because the body's cells do not divide while they are working. Repair is best done after a meal while making little motion. For many, a little TV and snacking is the method of choice.

### Recovery from exercise

Recovery from events that last less than a minute or two — such as sprinting or power lifting — does not require a higher intake of sugar or starches than usual. A normal diet has enough carbohydrates to refill the

glycogen stores in the muscles. Also, the recovery only takes 24 hours rather than the 48 hours needed for longer events.

Athletes in endurance sports need to eat foods such as sugar, potatoes, or bread to replace the loss of glycogen. On the day of the event, it does not matter if the source of the carbohydrate is simple (sugar, honey, fructose, etc.) or complex (bread, pasta, potatoes, etc.). Complex carbohydrates are better over the two days of recovery time.

Some exercises produce lactic acid. This lactic acid can be used as a fuel if oxygen can get to the muscle. Walking around while gently flexing sore muscles helps the body to burn the extra lactic acid. The acid can be exercised away in 20 minutes while resting could take over an hour.

## Baseball

There are three great mysteries of major league baseball. First, how does the infield fly rule work? Second, why do the players go on strike when they are being paid more in one year than many people make in a decade? Third, why do they still use wooden bats?

While this book cannot answer any of these great mysteries, it is worth exploring the question of bats. A possible reason for using wooden bats is that cork can be added to the middle to improve the chances of a home run. In every other way, metal bats are superior.

Several bats break in a typical major league game. Wood is simply not as strong as metals such as aluminum. (Of course, pure gold is soft, and the metal called mercury is even a liquid. However, few bats are likely to made out of gold or mercury!) Most bats for softball and amateur baseball are made from an aluminum alloy. More expensive bats can be made from titanium.

Besides withstanding more abuse than a wooden bat, metal bats come in a wide variety of weights and balances. By selecting the right bat, the hitting of almost any player can improve.

In case you are wondering why plastics are not popular for bats, plastics tend to be too light to hit the ball hard. Perhaps one day a plastic bat with a cement center will become popular.

## Winter Sports

So many sports take place on snow and ice that the winter Olympics take several days to complete. A short list would include skiing,

sledding, skating, and snowball fights. In all these sports, an intimate knowledge of water can be valuable.

Water is the most important chemical for human life in general and for winter sports in particular. Snow and ice are both solid versions of water. When water turns into ice, this is called a "phase change" by chemists. Chemists like to refer to materials that are solid as being in the "solid phase." They have invented this jargon because many materials can form several different types of solids when they freeze. In the case of water, "ice" or "snow" is an excellent way to describe the solid phase and even chemists will know what you mean.

Something odd happens when water turns into ice. As water goes down in temperature, at first it becomes more dense with its mass filling a smaller volume. This is normal because most liquids contract when cooled. However, water begins to expand at around 39 degrees Fahrenheit. The volume of the water continues to grow until it finally becomes ice at 32 degrees.

At the most basic level of water, there is a good reason for this behavior. However, I would not want to spoil one of the best parts of classroom chemistry. Only the results of this strange property will be explored here.

This expansion of water as it turns into ice explains why containers filled with water will burst if the temperature drops below freezing. Also, ice can float on cold water because it is less dense than the surrounding water.

The most important result of this quirk of water is that ice skating is possible. When pressure is applied to ice, the ice is pushed closer together at the surface. When the ice becomes more dense at the surface, it becomes water again. This is yet another example of Le Chatelier's principle. When the ice is in equilibrium and pressure is applied, the ice responds by changing a thin layer of ice back into the more dense liquid phase (water) while the rest remains as ice.

The fun begins when there is a thin layer of water on the ice. Water can be a great lubricant. Ice is notoriously slippery when there is water on it. Ice skating, sledding, and skiing are all based on nearly frictionless travel over watery ice.

## Water Recreation

Knowing the properties of water can help in both winter and summer sports. This should not be surprising because water is found all over the planet. While most winter sports require a street-smart understanding of ice, summer sports require some wisdom about liquid water.

Water covers about two-thirds of the surface of the Earth. Most of it is polluted and made undrinkable by a chemical called "sodium chloride" (also known as table salt). This type of water is often found in the great oceans of the world and is called salt water, sea water, or brine.

Chemists are hard at work trying to clean up Mother Nature's polluted oceans. A special type of material can filter out salt when salty water is pushed through a thin membrane of it. This process is called reverse osmosis. However, it would take too much energy to clean up the oceans with present technology. In the meantime, humans will just have to make the best of it with different sports for salt water and for fresh water.

People swim in both fresh water and salt water. Each type of water has its advantages and disadvantages for swimming. It is easier to float on salt water because the dissolved salt increases the density of brine. Fresh water has a density of 1. This means that one gram (g) of fresh water can be found in one cubic centimeter (cc) of volume or one pound per pint. Salt water has more mass per unit volume. It has a density greater than 1 g/cc. The more salt that is in the water, the higher the density, and the more things that will float on the brine.

Most humans with a chest full of air will float on fresh water. However, some people are denser than others. Certain people are so dense that they cannot even float on sea water. However, many people who cannot float on fresh water can float on sea water or salt lakes. Even if you can float, it is wise to use a life preserver to increase your buoyancy — that is, to make yourself less dense. The life preserver makes it easier to stay with your head above water.

Salt water requires a shower after swimming in it. Salt water evaporates from wet items (including human bodies) and leaves behind a thin layer of salt. This salt can make things look and feel grimy.

Another problem with salt water is that it tends to be more corrosive than fresh water. The salt can promote metal corrosion just like salted roads in the winter can promote rust on cars.

Finally, it is easy to run out of beer on the ocean and die of thirst. This is less common today than in the early days of sailing because of radios, planes, and party kegs. Still, careful sailors need to carry lots of fluids on ocean trips because drinking salt water can create toxic levels of sodium in the blood. For canoe trips on fresh water, it is less important to bring drinks because the water of many rivers is drinkable (but not always tasty).

In many sports, it does not matter whether the playing field is fresh water or salt water. Sailing and water skiing are pretty much the same on either type of water. However, fishing does change depending on the type of water. Certain types of fish love salt water and can be damaged if the concentration of salt goes down. Fresh water can enter their skin by osmosis (water's tendency to flow from dilute solutions into more concentrated solutions and thereby increase the randomness of the salt). This extra water in the skin of the fish can cause blisters and soon kill fish that are used to salt water.

As a result, fresh water fishing will catch different fish than salt water fishing. Common fish in fresh water include catfish, yellow perch, walleyed pike and crappies. Common fish in salt water include flounder, sea bass, sharks, tuna, and dolphins. (Actually, dolphins and whales are mammals, but let's not split hairs.)

## Enjoying the Great Outdoors

Staying inside climate-controlled offices and homes can easily make one forget the four elements of nature. If you have forgotten the four elements, do not feel bad because chemists have moved on to about 109 new ones. For those people with a flair for ancient history, the elements were first thought to be fire, water, air, and earth. These elements seem more real and important on the outside.

Fires can still be observed on camping trips. While water can be found in its bottled form in offices, water makes more of an impression when found in rivers and canteens. More air can be found at sea level than the tops of mountains or the bottom of the sea and people seem to appreciate things that are in short supply. The ancient element of earth can be found everywhere as dirt: the home of all types of flora and fauna (a fancy way to say plants and animals).

## Clean water

Home dwellers tend to take clean, drinkable water for granted. It comes out of the faucet in a variety of temperatures ready for washing or drinking (although most people prefer their water with some ice cubes). In the woods or on a boat at sea, water can become more valuable. Usually, the problem is not the lack of water (except in a desert). Water is commonly found all over the world. The problem is that most of the world's water is polluted (mostly by Mother Nature).

Sometimes campers will find water that is fresh but full of germs. A disinfecting chemical such as chlorine or iodine can often make such water drinkable. It makes the water taste bad, but it is better than dying from a terrible disease.

If the taste is a concern and you have fuel to burn, it is possible to do a simple distillation of dirty water. The water is heated to a boil and a cool, clean metal or glass sheet (maybe a lid) is placed just above the boiling pot. The water vapor condenses on the cool surface and pure water droplets run down the surface into a container for clean water.

A distillation leaves most of the impurities behind in the cooking pot and kills all of the germs. However, it takes a while and a lot of energy to boil away a pot of water.

**Simple Distillation Setup**
**(Less efficient than those in a lab)**

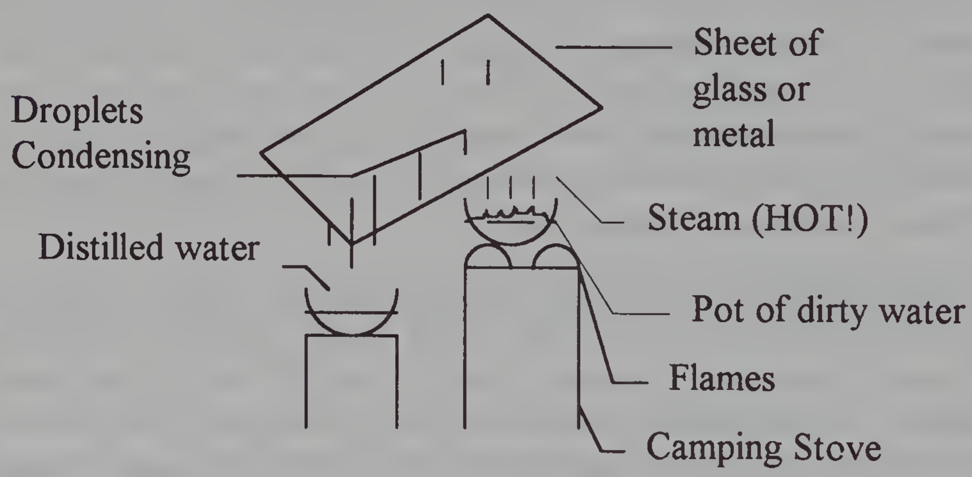



**Diagram of a simple distillation:** A pot of dirty water is heated on a camping stove. The steam condenses on a sheet of glass or metal. Droplets of distilled water fall into a bowl.

To give you an idea of just how much energy a distillation takes, think about how much heat that ice can absorb. Ice can keep food cold for hours. However, it takes far less energy to melt an ice cube than to change an equal amount of water into steam. The heat of fusion for water is the amount of heat it takes to change ice into ice-cold water. Water's heat of fusion is about 80 calories per gram (or 0.08 food calories per gram).

The heat of vaporization for water is how much energy it takes to change boiling water into steam. It is about 540 calories per gram (or 0.54 food calories per gram). Thus, it takes about seven times as much energy to change water into steam as to change ice into water. Distilling water can consume a lot of fuel for that reason.

Thanks to modern science, a portable unit to purify water can now be purchased for several hundred dollars. It uses a special type of thin film that lets water vapor pass through but leaves most impurities behind. One unit can produce a half-gallon of pure water per hour. For serious campers, this device may be better than carrying bottles of water or extra tanks of fuel.

## Camping stoves

Building campfires has a long history. For thousands of years, hunters and other travelers have cut down branches and collected brush to build these fires. Telling stories around a campfire is a tradition.

However, this ancient practice has some drawbacks. It takes a lot of work and destruction of plant life to build a good fire. The campsite damages the beauty of the forest. Also, the remains of the campsite tells any trackers that the campers are near. Finally, campfires can cause forest fires.

With the invention of modern camping stoves, more campers are going high-tech. Instead of gathering firewood, two pounds of stove and fuel can cook 10 meals.

A variety of fuels are used for camping. The most popular has been white gasoline (also known as camping fuel or Coleman fuel). It is almost the same as gasoline that goes into cars except white gasoline is free of additives. Coleman fuel must be carefully stored and used. Any spills of camping fuel can easily catch on fire.

Kerosene also comes from distilling crude oil but is less volatile than gasoline (that is, it boils at a higher temperature than gasoline). It is

slower to catch fire, and so its spills are less dangerous. Kerosene is more popular than Coleman fuel outside North America.

Other common fuels include propane, butane, and alcohol. Both propane and butane are gases at room temperature and atmospheric pressure. Pressure is applied by the containers to squeeze the gases into liquids. Because it takes thick walls to apply this pressure, containers of propane and butane tend to be heavier than those of gasoline, kerosene, or alcohol. On the bright side, neither propane nor butane will create the spills of flammable liquid that the other fuels can. Since butane is less volatile than propane, its fuel tanks tend to be lighter than propane tanks.

Alcohol is the only camping stove fuel that does not come from crude oil. It is often used on boats because fires from accidental spills can be put out easily with water. If water is thrown on a gasoline fire, the fiery gasoline will float on top of the water. If water is thrown on an alcohol fire, the alcohol will dissolve in the water and the flame will go out.

When comparing fuels, consider the temperature at which the stoves will be used. In cold weather, propane and butane fuels will come out of the tank slowly (if at all). Also consider the heats of combustion — how much heat is given off by burning a pound of fuel. While the heat contents of propane, butane, gasoline, and kerosene are fairly close to each other, alcohol only has 60% of the heat content of those other fuels.

Whichever fuel you choose, be sure to avoid spills due to wind or carelessness. Practice at home before using it on a camping trip (Remember: practice makes adequate.). Cook only in open spaces because a fire can quickly use up a lot of oxygen from the air. Most importantly, read the instructions until you know them by heart.

### Poison ivy

People who love doing yard work or camping in woods often learn about poison ivy and other irritating plants. These plants can cause allergic reactions in most people. Rashes often form after contact.

Just because the plant is dead does not mean that the poison is gone. The oily irritating agent, called urushiol, is not volatile. This is another way of saying that it will not evaporate easily into the atmosphere. Even samples of poison ivy that are one-hundred years old can cause rashes.

Whatever you do, do not burn poison ivy! The smoke will contain little droplets of urushiol that can cause big problems for those downwind of the fire. Breathing the smoke can cause injury or death.

As a rule, you have only a few minutes between exposure to urushiol and the binding of the oil to the skin. If you use that time well by washing thoroughly with cold water (and vinegar if you have it), you are likely to avoid the rash. Campers in the middle of a forest are often stuck with a rash because they have no way to wash off the poison. Also, a person may not know that he or she has been exposed until too late. A garden tool rubbed against poison ivy in the fall may still cause rashes the following spring.

Poison ivy can be treated in a few ways. None of the methods is very effective. Washing skin that was exposed to the plant with cold water and vinegar may help remove the poison before it irritates the skin. (Soap would remove oils that protect the skin.) Since the poison works by causing an allergic reaction, antihistamines used for treating allergies sometimes work against poison ivy. When antihistamines work, the results can be great, but they are not always effective. After a rash forms, lotions can be applied to the rash to reduce the itching.

In case of a rash, try not to scratch — not because it will spread the rash — but because it might cause an infection. A doctor can suggest several ways to reduce the suffering until the rash heals. As always, follow the directions of the doctor and the label carefully. Also, be careful about mixing medicines because they often interact to cause problems.

A report in *Chemical and Engineering News* hints at a Chinese folk-medicine cure for poison ivy. It seems that Chinese craftsmen have long used a latex similar to the poison of poison ivy to make bowls and boxes. The poisonous secretions from the plant (which is related to poison ivy) are collected, shaped, and hardened to form a solid object.

A discovery was made about 2,200 years ago. By that time it was well known in China that the sap of this plant caused severe allergic reactions similar to poison ivy. One day a crab walked into a batch of the deadly latex. To the surprise of the craftsman, that batch refused to harden in air. Apparently, something in crab juice inhibits an enzyme in the sap. Since poison ivy is similar to the Oriental latex, it may be worth buying some fresh crabs to test out this remedy.

Note that this discovery was stumbled on. It is too easy to overrate logic and carefully planned studies. Simply thinking about unusual events has always been a major source of new science.

## Sunlight on skin

Ultraviolet (UV) light cannot be seen by the human eye but reacts with skin or eyes to cause damage. Most people have special enzymes to repair the damage from ultraviolet light. Some types of bacteria (and maybe vampires) are not so lucky and are killed by sunlight. Because it can kill some types of bacteria, sunlight helps to sterilize cloth such as baby diapers.

Exposing skin to sunlight darkens the skin due to its effect on the skin's melanin. When ultraviolet light hits skin, the melanin changes to its oxidized dark-brown color. Tanning that lasts more than a short time requires a longer exposure to ultraviolet light. This starts the production of melanin. The new melanin makes the tan last more than just a few hours. Also, skin tends to thicken with exposure to sunlight.

Sun lamps result in quick tanning that lasts for, at most, a few days. Light from the sun includes high-energy ultraviolet light that can cause "true tanning" in the same sense that leather is tanned. Sunlight can cause wrinkled and sagging damaged skin. Suntan booths are pretty good about screening out the damaging rays and thus are safer for skin.

A tan is currently considered to be a sign of wealth, and for that reason, is highly prized. In the days when laborers worked in the field, pale skin was highly prized — again, as a sign of wealth. It might be cheaper and healthier just to walk around with a suit made of money. (I get a little jealous when the subject of suntans comes up because — like most people of Irish descent — I cannot tan.)

For those people who can tan, a strategy to look good for a date or job interview is to go to a suntan booth on the day before the big event. The booth will provide a quick tan. After the date or interview, the skin will quickly go back to its normal color with no lasting damage. The good first impression could be worth the cost of tanning fees.

Sunscreens are liquids applied to the skin to prevent the burning ultraviolet light from reaching the skin, causing sunburn, and starting true tanning. Many plastics and many types of glass will also screen out the harmful UV light. Therefore, sunscreen is rarely required behind closed

windows. After the UV light is screened out, any reddening of the skin is due to heating the skin.

Many sunscreens are water-resistant. They are made of hydrophobic ("water-fearing") chemicals that do not easily wash off in water. In fresh water, these liquids wash off only slowly. Salty water is even less like the sunscreen and — following the old rule that similar liquids dissolve each other ("like dissolves like") — the sunscreens dissolve more slowly into salt water. Sunscreen that might last one hour in fresh water may last two hours in sea water. Of course, sunscreen will last only seconds in a washing with water and soap. (Note that all soaps are partly hydrophobic and partly hydrophilic ("water-loving"). The hydrophobic part of soap dissolves materials such as sunscreens while the hydrophilic part keeps the soap dissolved in water.)

Sun-blocking lotions have protection numbers on them. A number of 4 lets more ultraviolet light through than a number of 30. People who are willing and able to suntan, but who do not want to go indoors after only 15 minutes of sun, can stay out longer with less chance of severe sunburn if they use a sun block with a low number. Those people who are not trying to suntan can use a sunscreen with a high number (such as 30) to avoid sunburn over several hours of outdoor activity.

A good sunscreen should not cause problems if absorbed through the skin. (Some sunscreens can cause problems for people who must avoid salicylates in foods.) Also, the sunscreen should not stain clothing or towels.

### Sunglasses

Sunglasses protect the eyes against bright lights. However, many people wear sunglasses too often. (One singer in the 1980s even claimed to wear his sunglasses at night — a very poor policy while driving.) Healthy eyes can protect themselves against sunlight.

Some cheap sunglasses can actually harm the eyes by blocking visible light (causing the eyes to open wide), but not blocking the harmful UV light. To avoid eye damage, make sure that your sunglasses block ultraviolet radiation.

## Cosmetics — Natural and Artificial

Some people prefer natural cosmetics despite the extra cost. Natural ingredients are promoted as making the products work better, be

safer, or help protect the earth. Actually, these products are often no better than other products.

The plant extracts that go into natural cosmetics are a mess of various chemicals. Because makers of petroleum-based cosmetics start with purer ingredients, it is easier to create lotions that work and are safe and reliable. Purifying plant extracts to make safe and reliable lotions often produces waste as well.

Buying on price and good performance is much smarter than buying on claims that the product is "all-natural."

### Moisturizers

Moisturizers are creams that replace lost moisture and make skin more flexible. These creams are emulsions — stable mixtures of oily materials and water. The water penetrates the skin while the oily materials slow the water's evaporation.

Some modern moisturizers contain fruit acids such as citric acid, malic acid, and lactic acid. (Many fruits also contain these acids.) The fruit acids remove dead skin and leave the remaining skin smoother and tighter. These lotions can sometimes reduce liver spots and wrinkles — making skin look younger.

### Lipstick

Lipstick is mostly castor oil and wax. It must be carefully measured and mixed together by the maker so that it can go on smoothly and cover well without changing the taste of food. It also must be stable to temperatures up to and a little beyond 100 degrees Fahrenheit. The colors must not be soluble in water or they would be quickly licked off. Finally, the lipstick must be safe to eat. It is no simple task to produce a good lipstick.

### Perfume

Do not judge a perfume by its source. Many natural perfumes suffer drawbacks such as higher prices or changing into foul-smelling compounds on the skin. It is often cheaper to make a perfume from bottles of chemicals rather than collect the chemicals from plants or animals and then purify the resulting mixture.

For example, artificial musk smells much like the natural musk from the male musk deer. The difference is that the natural material costs 200

times more, and members of this endangered species have to be killed to make the natural musk.

A natural or synthetic musk adds a leathery or musky note when added to a perfume. Musk also lets a small amount of perfume last a long time. Some flower children of the 1960s smelled like musk for four days.

However, musk is not the longest-lasting perfume. That honor goes to a fragrant oil called "kyphi." King Tutankhamen was buried with some of it and after over 3,000 years, traces of this scent could still be detected. It would be fair to say that the king got his money's worth. Who says you can't take it with you?

Cheaper versions of expensive perfumes are worth trying. In most cases, they have the desired effect at a fraction of the cost. Keep in mind that manufacturers pay $3 to $4 per ounce wholesale for the perfume ingredients. The fancy bottle sure costs a lot!

### Pheromones — irresistible perfumes

A female cockroach can excite male roaches into a mating frenzy with her scent. Many people would like to have that effect on members of the opposite sex. So far, no human pheromone has been found (at least as of mid-1991). Do not count on your perfume to do more than bring back memories. Of course, modern chemistry can let you excite roaches around you into a mating frenzy.

### Pretty hair

The condition of hair depends on the transparent plates that cover strands of hair. When these plates are in place undamaged, the hair reflects light and has a glossy look. However, a variety of problems arise when too much heat from a hair dryer, harsh chemicals, or constant brushing wears away the hairs' outer covering. The hair begins to look dull. The hairs no longer slide past each other smoothly and start to tangle with each other. The loss of moisture without the hairs' protective covering can dry the hair.

Hair conditioners are designed to lubricate the hairs so they can slide past each other smoothly. The conditioners protect the hairs' outer covering and thus aim to avoid all the problems above. If you can comb your hair without suffering tangles, your conditioner is doing its job.

Shampoos and conditioners combined into one liquid can be very nice. For example, travelers only have to carry one bottle instead of two.

However, people willing to spend extra time on their hair may still prefer the old system. The older system usually produces either better results or lower cost.

The slightly better results from the two-bottle system are due to difficulties in making the all-in-one product. Surfactants are chemicals that change the surface tension of a liquid; that is, how tightly a liquid holds together. Shampoos use anionic (negatively charged) surfactants to remove dirt and oils from the hair. Conditioners use cationic (positively charged) surfactants to coat the hair with an oily film that helps lubricate the hair. A problem arises when making the all-in-one product because negatives attract positives. Shampoos will react with conditioners to form an oily mess if not stabilized by another chemical.

This stabilizing chemical is often an amphoteric surfactant. An amphoteric chemical has properties of both an acid and a base. A material such as this is added to the bottle to keep the shampoo and conditioner apart. This keeps them from reacting with each other.

Still, compromises have to be made in all-in-one products. Too much conditioner can cause problems in these formulations. If your hair requires extra conditioning, you would be well advised to use a separate conditioner. Also, if you are looking for the lowest cost hair care, you may find that the cheapest shampoo and the cheapest conditioner cost less per washing than the cheapest all-in-one product.

A new advance in hair care that shows great promise is the use of cell membranes in hair lotions to repair the outer layer of the damaged hair. Cell membranes are the part all living cells that divides cells into compartments. The membranes keep the enzymes and proteins in the cell from intermixing and destroying each other. Cell membranes are also used on the outside of hair for protection. This product seems to rebuild the hairs' outer layer. It goes under the name of Senscience and may be worth a try if traditional conditioners do not work.

Hair can be dyed a variety of colors for either a short time or more permanently. To dye hair a darker color for a short time, particles of the desired color can be deposited on the hair. These particles are easy to remove but will not turn dark hair into blonde hair.

To turn dark hair blonde, it is necessary to break out the harsh chemicals. Hydrogen peroxide softens the outsides of the hairs to let the dyes inside the hair. At the same time, the natural color of the hair (melanin) is bleached by the hydrogen peroxide to allow lighter colors.

The presence or absence of curl in a head of hair can change a person's appearance. Sometimes, even close friends may no longer recognize the person. Despite the big impact on someone's looks, most hair can change its curl with a little heat or moisture (humidity). When humidity is high, it can easily change an expensive permanent into a bad hair day.

The chemicals that make up hair are directed by delicate chemical bonds. A little heat or moisture can interfere with these bonds and temporarily change the twist of the hair. Wetting and blow drying hair can give an inexpensive, one-day curl.

Hair spray, a solution that changes into a polymer on the hair, can make the hair stay in place longer than simply wetting and blow drying the hair. Wetting, brushing, and blow drying followed by hair spray can produce curly hair for one day without seeing a hair stylist. However, the brushing and heat can damage the transparent plates that cover the hair. This can cause damaged hair and all the problems that go with it. For this reason, the quickie one-day permanent is not something that should be attempted more than once a month or so.

If a more permanent curl is desired, it is time to see a hair stylist. These people know how to use sulfur-containing compounds (smells like rotten eggs) together with peroxide to create a permanent. Trying this at home can be a problem because the same chemicals will remove hair.

Speaking of which, baldness is a problem for about 40% of men (and a few women). The pattern of baldness is inherited. Until recently, there was no proven cure. Even today, it is easy to find people who peddle questionable treatments like brushing the scalp or applying chemicals to clean the scalp. Both of these treatments have poor records of producing more than a stubble.

There is still hope for the toupee wearers of the world. A high blood pressure drug called "minoxidil" not only treated patients for the blood pressure problem but as a side effect produced growth of hair in scalps that had been bald. Only about a third of patients were "cured" of baldness. However, once a chemist finds a partial cure for a problem, he or she can try thousands of related chemicals until a complete cure is found. The problem with some remedies is that hair grows all over the body rather than just the scalp. Also, the Food and Drug Administration (FDA) is slow to approve anything.

### Toothpaste

Toothpaste is made of particles of polishing agents suspended in a polyalcohol such as glycerol or sorbitol. To scrape away plaque without damaging teeth, the particles have to be harder than the plaque but not harder than the teeth. Some chemicals are added to stabilize the mixture. Others give a little foam when brushing takes place.

In a rather clever bit of science and marketing, some toothpaste makers hide the abrasives in their toothpaste. They choose the refractive index (how a material bends light) of the liquid part of the toothpaste so that it matches the refractive index of the abrasive. As a result, the abrasive becomes invisible inside the toothpaste. All of the translucent gels use this technique. While these toothpastes are prettier, they are no better or worse than other toothpastes.

## Siesta Time Strategies — TV and Movies

People are alert and creative during only a few hours of a day. These hours, determined by the biological clock, are far more valuable than other waking hours. People are awake another 8 to 10 hours, but are not as alert in the non-peak hours Creative work becomes nearly impossible. Driving a car during non-peak hours is somewhat dangerous. Since so little can be done during this time, some people stand around and talk to coworkers. Those people who do not have to work can take naps, watch TV, or a movie.

TV watching takes more time (on average) than any other leisure activity. The average time spent watching TV is over two hours per day in the United States. Watching TV is nice because it requires no creativity. It does not matter if you can follow the stories. TV watching fills the dead space of non-peak hours in a mildly amusing way.

Some TV programs teach subjects such as chemistry. With VCRs, people can play science videos during non-peak time. Of course, maybe one person in a million enjoys watching science videos that much.

# Chapter 4

# Food Chemistry

Working in a kitchen is the closest that most people come to doing chemistry experiments. Cooking is simply using heat to change the chemistry of food. When a cook discovers that adding some sugar improves the flavor of a dish, this is a chemical finding just like those from high-tech labs. Many labs are actually looking for that type of result to improve the flavor of their TV dinners or other packaged foods.

This chapter is rich in the type of chemistry that is taught in classrooms. Because there is so much food chemistry to learn and because a large chunk of most families' paychecks goes toward food, this is the longest chapter of the book. With the help of this chapter, many readers should be able to eat nutritious meals while saving either time or money or both.

## Flavors

The four basic flavors are bitter, sour, salty, and sweet. Sour is your tongue's way of telling you that the food is acidic, or as a chemist would say, the food has a low pH. Salty usually means that the food contains table salt. Bitterness and sweetness are not well understood. This means that science cannot help you with any "bittersweet memories."

Most foods are not simply sweet or sour or bitter or salty. Much of the artistry of cooking is in the careful blending of various chemicals with different flavors. For example, a study of low-fat cheddar cheese showed that salt was important to the flavor of the cheese. Even though cheddar is not commonly thought of as salty, a salt content of 1.8% enhanced the flavor while masking the bitterness of the cheese. Some people add salt to

most foods to improve the flavor. As the old expression goes, it is largely a matter of taste.

While there are only four basic flavors, a large number of combinations of these flavors are available. Between 1,100 and 1,400 flavors can be used for food. These include both "natural" and "artificial" flavors.

### MSG

Monosodium glutamate (MSG) is widely used by cooks throughout Southeast Asia. They are convinced that a pinch in every pot brings out the flavors of the food. While many people enjoy the extra flavor, some people are sensitive to MSG. These people suffer Kwok's disease if they consume even small amounts of it.

Some people try to make a moral statement by what they eat. I once sat in a Chinese restaurant happily eating my lunch when two college brats dressed in black shorts and black T-shirts sat down at a nearby table. They both ordered the broccoli and both announced quite loudly that they did not want any MSG. It would be unusual for both to be sensitive to MSG; so, either they were trying to be self-righteous, or they did not like the taste of broccoli. I am inclined to believe the latter. Still, at the time, I was tempted to order dessert with a double helping of MSG.

### Artificial flavors

Scientists can re-create complex flavors with the help of powerful analytical tools such as chromatography. Chromatography separates a mixture of chemicals into two or more pure chemicals. It does this by moving the mixture next to a stationary material. The more time the chemicals in a mixture spend dissolved in the stationary material; the slower they move. Because of the rule of "like dissolves like," the chemicals in the mixture most similar to the immobile material move the slowest.

For example, suppose an oily material and a salt are flowing in a watery mixture over an oily tar. The salt spends most of its time in the watery layer while the oil spends most of its time in the tar. This can lead to the separation of the salt and the oil because the oil spends most of its time trapped in the nonmoving tar. The salt travels along with the moving watery mixture. To separate the salt, just trap the oil inside the tar, collect the watery mixture, and evaporate the water from the salt residue.

Another technique called gas chromatography (GC) can separate mixtures of volatile (easily evaporated) chemicals. This method begins by heating the mixture to change it into a gas. Ideally, the entire sample will vaporize because this method cannot analyze any solids that are left behind. Even though most foods create a very complex gaseous mixture, GC can separate most mixtures of gases into pure chemicals.

GC is similar to liquid chromatography (the example with an oil and a salt flowing in a watery mixture over tar). In GC, the watery and oily gases from the vaporized food are blown over a tar. The oily gases spend more time in the tar than the watery gases. The watery gases will pass through quickly, but the oily gases come out later. The more oily the gas is; the longer the time it spends in the machine.

When gases come out of the gas chromatograph (GC), scientists can use a variety of methods to detect and identify the gases. The methods range from shooting an infrared beam through the gas to smelling the gas as it comes out. Although just smelling the gas cannot give its exact chemical structure, it helps to determine how each gas smells and tastes. Flavors can then be re-created by mixing the pure chemicals together.

Mixing chemicals together to form artificial flavors is often done because it can use chemicals from cheaper or better sources than the original food. The new flavor sometimes uses only some of the chemicals from the natural flavor. Often, only a dozen or so chemicals in a food contribute to its flavor. A simpler artificial flavor often smells and tastes just like the natural flavor to most people. The flavoring chemicals can be the same as in the natural food.

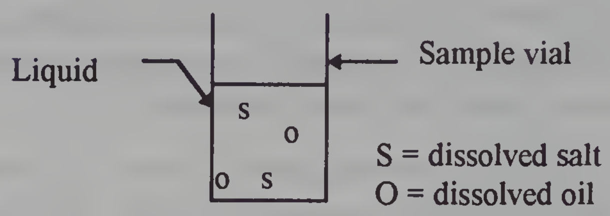
As a rule, natural flavors are no better than artificial flavors as long as both taste the same.

One further note about chromatography: When plant breeders tried to cross an onion with garlic (perhaps to reduce the list of ingredients for lasagna?), the problem became one of figuring out if the cross-breeding had worked. After the new plant was mature, it was chopped up and the volatile chemicals from the plant were passed through a GC.

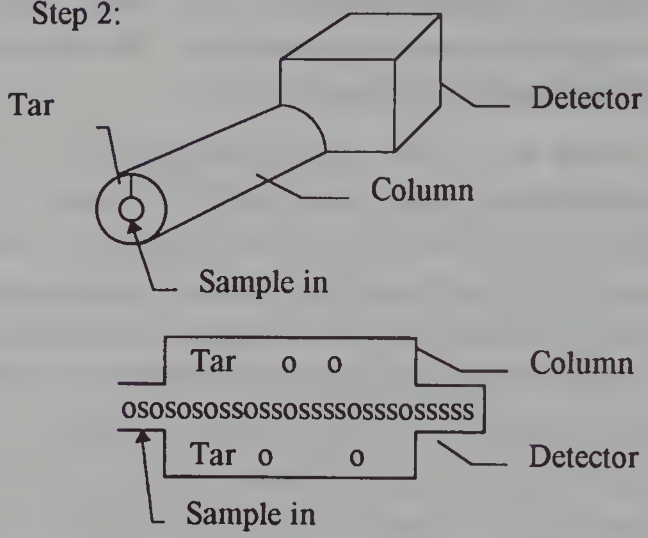
The biochemists were pleased to see chemicals characteristic of both onions and garlic coming from the new plant. Before the GC was invented, expert taste testers would decide if the new plant was a success. The new machine gives a much more precise and detailed response.

## How Chromatography Works

Step 1:



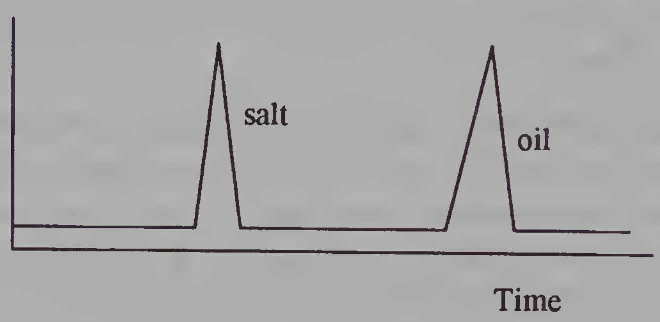

Step 2:




**Run Sample through Column**

Step 3:

**Detector Output**




**Step 1:** Sample of dissolved oil and salt prepared.
**Step 2:** Sample run through column into detector.
**Step 3:** Column lets the salt go through faster, and the detector tells the chemist when the salt or oil is coming out of the column.

## Sweetening experiments to try

In general, this book avoids any sort of chemistry experiments. This is a little exception. Being an experiment, it might not work. If it does not work, well, nothing much is lost. If you like the result, you have invented a new recipe.

The experiment is replacing regular sugar with a sweeter type of sugar — thus permitting you to use less. It has been found that fructose is 73% sweeter than sugar and invert sugar such as honey is 24% sweeter than table sugar (also called sucrose). Try using five-eighths as much high-fructose sweetener as the instructions call for sugar or four-fifths as much honey in place of the sugar. It should be just as sweet and have fewer calories. However, you may or may not like the change in the texture of the food. Good luck!

## Aspartame

Aspartame (part of NutraSweet) is not a carbohydrate such as sugar, honey, or fructose. It is a type of protein called a dipeptide. About one person in 15,000 has a rare genetic condition called phenylketonuria that can make a person sick after eating aspartame. If you read the labels on products containing NutraSweet, you will find a mention about this problem.

## Polyhydric alcohols

Polyhydric alcohols (so-called because they are related to alcohol) are used to prevent food or tobacco from drying out. Also, they are used as a sweetener in sugarless chewing gums. Examples of these alcohols are mannitol, sorbitol, glycerol, and xylitol. Glycerol might be considered "natural" while xylitol may not. However, all of them are closely related chemically and all have similar flavors.

(Note that all of their names end in "ol." The scientific names of all alcohols end like this. The common names of alcohols do not always end that way. For example, glycerol is also called glycerin.)

## Texture as part of flavor

People expect their foods to have good textures. If the food is crunchy when it should be creamy, the food seems to have a different flavor. Most people prefer their food to have well-known textures.

For example, homemade ice cream can become gritty if it is thawed and refrozen. On refreezing, water crystallizes as little ice chunks and the milk sugar forms little sugar crystals. Since much of the fun of eating ice cream is its smooth, creamy texture, most commercial ice cream has gelatin, algin, or carrageenan to keep the texture smooth. Texture may be the reason that bubble-gum ice cream never caught on.

### Colors as part of flavor

Many foods are colored using small amounts of natural or synthetic dyes. Many of the artificial dyes originally came from coal tar. The natural dyes usually come from plants.

Colors can be important in helping a person identify what types of food he or she is eating. If orange juice or raspberry juice has an unusual color, most people will find it hard to figure out what they are drinking. Since raspberry is a more subtle flavor, color is more important for it.

## Cooking

Cooking changes food to make it safer or tastier. Heat kills germs and parasites in raw foods. Also, heat changes the chemicals in food. Often, oxygen will react with the food while the food is cooking, and complex chemicals will break into simpler ones.

A color or texture change will often result from cooking. Beef will change from red to brown as it is cooked. Seafood, chicken, and pork will change from pink to white when heated. Apparently, some highly colored chemicals in the food change color as the food is cooked.

Likewise, the texture of many types of food change upon heating. Cooked meat is less slimy than raw meat. Fruits and vegetables tend to be softer after cooking because the cellulose that holds these foods together is weakened.

After cooking, the food's new texture and color are usually more attractive. The food becomes safer to eat and is often easier to store. For example, milk and beer are pasteurized by heating the liquids to kill germs. They can then be stored in sealed containers without colonies of germs growing in the liquid. Untreated milk or beer will spoil quickly.

Cooking often makes foods more digestible. The human body cannot digest many types of large carbohydrates. If you carefully observe cows for a while, you will notice that they never cook their food before they eat it. They eat all kinds of vegetables and grains raw. Cows can do

this because they have a better digestive system than humans. Cows have four stomachs that convert materials such as cellulose into simple sugars that the cow can use. Human bodies cannot do this. Therefore, many raw vegetables and grains are merely sources of fiber for us.

One example of the benefits of cooking is the preparation of the South American quinoa. While the plant is rarely eaten in most of the USA, it is a common food in some parts of South America. Quinoa is always processed — never eaten raw.

To see what would happen if it was eaten unwashed and unprepared (so that it would be naturally bitter), some rats were fed a diet of raw quinoa. The rats disliked the food and tried to avoid eating it. Some natural chemicals in the plant called "saponins" caused the problem. Processing can dramatically reduce the levels of saponins. Processed quinoa can be a valuable source of protein and has a flavor somewhat like a wheat cereal.

## Measuring systems for cooking

Most cookbooks in the United States use measures such as cups, tablespoons, and teaspoons. Chemists abandoned this system long ago. It was just too hard to scale-up a reaction using this system.

For example, suppose you want to double the size of a recipe that calls for one-third cup of sugar, one cup of flour, two teaspoons of salt, and one cup of water. When the recipe is doubled, the sugar goes from one-third cup to two scoops of the one-third cup. One cup of flour in the old recipe becomes two cups of flour in the new recipe. The water also goes from one cup to two cups. (Note: Two cups of water is a pint that weighs one pound.) Finally, the salt goes from two teaspoons to four teaspoons, but a quicker way to measure it would be to use one tablespoon and one teaspoon.

The following conversions may prove useful: Sixteen tablespoons equals one cup. Three teaspoons equals one tablespoon. One pound of water equals two cups or one pint.

This seems easy. I wonder why chemists threw up their hands in disgust over this system?

Let's try reducing the recipe by a third. (Maybe the recipe serves six, but only four people will be eating.) In this case, one cup of water becomes two-thirds of a cup. You can just read it off the side of the measuring cup — no problem! Likewise, one cup of flour becomes two

scoops of the one-third cup scoop. (Hey, chemists should have thought of that!)

The problems begin when the hapless cook tries to cut the one-third cup of sugar by a third. Most measuring sets do not come with a one-ninth cup scoop. (It would actually be two-ninths of a cup.) Also, reducing two teaspoons by a third can be a problem. It is one and a third teaspoons, and most measuring sets do not have a one-third teaspoon.

Dimensional analysis could help with these problems, but it is easier just to approximate. An experienced cook would just use a heaping one-quarter teaspoon as a one-third teaspoon. Cooking is often closer to an art than a science, anyway.

The trick to chemistry is to produce results that can be re-created in different labs. While cooks can vary the salt a little from dish to dish without any problem, chemists will often get different results by making mistakes of that size.

The metric system makes changes in the scale easier to calculate and measure. If the recipe calls for 100 milliliters of an ingredient and you want to reduce the scale by a third, it is easy to calculate that 67 milliliters should be used. If the recipe calls for 28 grams of flour (about one ounce), reducing by a third is a simple matter on an electric balance. It is simply 28 grams times two-thirds or about 18.667 grams.

The whole system is based on multiples of 10. One kilogram is one thousand grams. One gram is one thousand milligrams.

This book will not explain the metric system in detail because the old system is not likely to be abandoned. It just has too much popular support for that. Most people try to avoid learning new things after getting their diploma. By keeping the old system, they do not have to learn new units such as liters, grams, and meters.

Serious readers can learn about it from an encyclopedia. Learning the metric system can be worthwhile if you plan to do any traveling because the rest of the world uses it.

### Cooking chemistry

Inside plants such as barley, peas, potatoes, wheat, rice, and corn are tiny grains of starch, one type of carbohydrate, inside a cellulose covering. Cellulose is also a carbohydrate but is more rigid. It is used by the plant to keep the contents of one cell from seeping into another. If the

food is eaten raw, the human body will have trouble reaching the starch because humans cannot digest cellulose.

By cooking the food in boiling water, the starch swells with water and bursts through the cellulose covering. This creates a gel of starch and water that is easy to digest. This is a major reason why these foods are often boiled before eating. Because cows can digest cellulose, their food need not be boiled.

Cooked food is sometimes heated for a second time. This is the case when baked bread is toasted. The starches in the bread break into smaller starches called "dextrins." These smaller starches are easier to digest than the larger variety. The body can quickly capture the energy in the bread and raise serotonin levels in the brain — producing a feeling of calmness. This may be why toasters are so popular. Also, thinner slices toast more thoroughly. This may be why every new invention is compared to the invention of sliced bread.

Boiling food has its good points and its bad points. It can make the starch more accessible. It also destroys most of the enzymes and other natural poisons in the plant. However, most of the vitamins and minerals are drained out along with the boiling water.

A good way to keep the nutrients in the food is to stew the vegetables along with ingredients such as meat. No vitamins or minerals are drained away from such a dish. However, some vitamins such as A, C, D, riboflavin, thiamin, and folic acid are not stable to heat and, thus, may be lost by stewing.

Boiling for shorter times rather than longer times can help. Shorter boiling times decrease the losses of heat-sensitive nutrients. Reducing the surface area of the cooking food can also help. One ounce of spinach may have much more surface exposed to boiling water than one ounce of foods such as potatoes, tomatoes, or even peas. A small surface area can slow the losses of nutrients into the water.

## Oiling cookware

Many recipes call for oiling baking dishes and cookie sheets before cooking food. Oiling keeps the food from sticking to the cookware by changing the cooking surface.

Water from the food can wet an untreated surface. Heat from an oven or a stove will rapidly evaporate this water. Most water-soluble ingredients such as salt or sugar that were dissolved in that water remain

behind after the water is gone. The solid residue coats the cooking surface and creates a new surface that sticks to food tightly. Most cooks dislike cleaning pans like that.

Oils, nonstick pans, and nonstick sprays all work by changing the cooking surface so that water will not wet the surface. An oily surface repels the water. This lets the water remain in the food and evaporate from there. The salts and sugars also remain in the food. An oiled dish is usually easy to clean.

Be sure to wash dishes that were oiled for baking. If the dishes are allowed to sit unwashed, the oil can react with itself to form a tiny polymer (plastic) film. This film can build up and cause food to stick to the dish the next time it is used.

### Fires in the kitchen

Grease fires are a major cause of fire damage. Fire extinguishers are the best way to put out these fires. If you do not have an extinguisher around but need to put out a grease fire, the first rule is to avoid pouring water on the fire. The water will not get between the grease and the flame, and the fire will continue. The water will just provide a platform on which the grease can burn. The grease fire will probably spread if water is dumped on it.

If you do not have a fire extinguisher, baking soda or a mixture of baking soda and sand poured on the burning grease can put out most grease fires. The baking soda cannot catch fire, and when heated, it releases carbon dioxide. The carbon dioxide puts out the fire because it prevents oxygen from flowing to the base of the flame. All fires need heat, fuel, and oxygen (or other oxidizing material). When oxygen is blocked from the flame, the fire quickly dies.

Cooking greasy meals such as steak or deep-fried foods make grease fires more likely. Heating greases requires careful attention. If the oil begins to smoke, the heat must be reduced or the grease will likely catch fire. Each time fat or oil is reused, it reacts with oxygen to start smoking at a lower temperature. Because old oils are so likely to smoke, fresh grease should be used after a while.

### Physicists and cooking

If physicists were good at cooking, they would be chemists. I discovered this back in high school when one of my fellow students wanted to know why water in a pot boils faster when the lid is on the pot. This

was actually a very good question. The answer involves hot steam being trapped by the lid. Without the lid, the energy in the steam would heat the room rather than the pot. The steam would make the air conditioner work harder (or cause you to leave your kitchen).

This high school physics teacher did not know to apply the law of conservation of energy — the first law of thermodynamics. The first law of thermodynamics allows people to keep track of energy like an accountant. It says that the energy being pumped into that pot by the stove does not just disappear. By keeping the high-energy steam in the pot, the energy in the pot increases faster. Instead, this teacher said that since a watched pot never boils, putting a lid on the pot makes it seem to come to a boil faster.

As it turns out, the physicists at the college level are slightly better cooks. However, they still have trouble boiling water.

One of my college-level physics teachers claimed there is no difference between a slow boil and a rapid boil. He argued that the water was converted into steam at the same temperature no matter how fast the water was boiling.

The main problem with this argument is that it flies in the face of many centuries of cooking experience. The water must first come to a rapid boil to be sure that it has reached its boiling point. Otherwise, the cook can easily be fooled into thinking that those first few bubbles means the water is at a slow boil. The heat at the bottom of the pot can cause local regions of steam to form bubbles. While those areas are at boiling temperature, the rest of the pot does not heat up to boiling temperature until there are lots of bubbles of steam.

Still, the college physics professor had his moments. He pointed out that the boiling temperature could change with pressure. At high altitudes where the pressure is low, the boiling temperature is lower than at sea level or in a pressure cooker. Pressure cookers increase the pressure on top of boiling water. Increased pressure raises the boiling temperature, and causes the food to be cooked at higher temperatures. This speeds up cooking time (saving time) and cooks the food using less energy (saving money in energy bills).

### How microwave ovens work

Microwave ovens cook much faster than regular ovens because much more of the energy goes into the food. Microwave ovens cook by heating the water inside the food. Since most foods contain lots of water

while microwave cookware contains little water, it is possible to heat food while a plate below the food stays cool.

Conventional ovens heat from the outside in. It takes some time for the heat to travel to the center of the food. The food cooks from the inside out in a microwave oven because microwaves can penetrate the food. Of course, microwave ovens are also well known for heating food unevenly. Stirring and rotating the food can help.

### Home cooking (my lasagna story)

When learning a new recipe, it often takes a while to get it right. For example, I once tried a recipe for lasagna that promised to be cheaper and better than frozen lasagna. Frozen lasagna costs about 13 cents per ounce and took a little over an hour to prepare 21 ounces. (A microwave oven would cut that to 15 minutes.) The only dish to clean after cooking the frozen variety was a fork. Since I liked the taste of the lasagna so much, I wanted to try out the recipe.

The first time I made lasagna, I needed to buy a four-quart dish; cans of tomato paste and crushed tomatoes; bottles of garlic, basil, oregano and olive oil; whipping cream; onions; ricotta and mozzarella cheeses; Italian sausage; ground beef; flour, eggs, and salt (for noodles); and a rolling pin (also for noodles).

The noodles were made from scratch and took 1.5 hours to make. I figured that the ingredients for the noodles cost 38 cents. This was quite a savings over the commercial price for noodles of 95 cents. Still, that worked out to \$0.38 per hour. (See equation 4-1.) I valued my time more highly than that.

$$\frac{\text{Savings}}{\text{Time}} = \frac{\$0.95 - \$0.38}{1.5 \text{ hours}} = \$0.38 \text{ per hour (Equation 4-1)}$$

Preparing the lasagna and cooking it took 2.5 hours. My years in chemical laboratories came in handy. I had three burners going at once cooking the sauce, onions, and meat. I also washed most of the dishes while the lasagna was cooking. If I had tried to make it while I was in high school, I would have used only one or two burners, and it would have taken twice as long.

It cost \$38 and four hours to make about 100 ounces of lasagna. Unfortunately, the recipe did not include enough tomato cream sauce (a

type of spaghetti sauce). It came out dry and very heavy. Eating a small square was enough for a whole meal. It cost three times as much as the frozen variety and did not taste as good. However, I learned a lot from making it that first time and my kitchen was now better equipped.

Since I did not have to buy any more dishes, I saved a lot of money the next time I made it. I waited until some of the ingredients went on sale. I bought the noodles rather than making them from scratch — saving 1.5 hours. I added another 3.5 cups of tomato cream sauce and several ounces of parmesan cheese to improve the flavor. The result of all these changes was a dish of lasagna that approached the flavor of the frozen variety, took 2.5 hours to prepare, and cost about the same as the frozen variety per ounce.

The leftovers were both the best and the worst part of the experience. The recipe made enough lasagna to feed six people. Since I was cooking for myself, I had about five servings as leftovers. It was quick and easy to reheat as much as I wanted. However, the same dish day after day began to wear out its welcome. By alternating lasagna with my low-cost specialty, macaroni and cheese with tuna and peas, both dishes tasted better and the nutrition was also better. By eating traditional breakfasts of eggs, cereal, and pancakes and starting each dinner with a salad, the lasagna remained a welcome part of my diet.

## The Basic Nutrients — Fats, Carbohydrates, and Proteins

The most basic food groups are not fruits, vegetables, breads, meat, and dairy products. These old food groups reflected the national diet of the United States in the 1940s. From long experience, it was clear that most people could live healthy lives while on this diet. If some people in their sixties developed heart disease, it was a small price to pay for a healthy life up to that age.

There were at least two problems with the old-style basic food groups. First, the recommended serving portions were largely politically determined. If dairy farmers could effectively promote milk, then the number of recommended daily servings of milk might go from 2 glasses to 3 glasses per day. Likewise, if the wheat farmers knew the right people, the servings of bread might go from 4 to 5 servings per day.

A more basic problem with the food groups is that the groups did not reflect the chemical makeup of food. According to the food-group theory, vegetarians all over the world are slowly dying of malnutrition.

Those people who read the fine print at the bottom of the food-group chart would find that beans or nuts are an acceptable substitute for meat. How can beans or nuts sometimes substitute for meat? A bean plant is not an animal, and beans are not meat.

The answer is that both are rich in protein. It is the chemicals in the food that matters — not the source of the food. Whether from a plant, an animal, bacteria, or a chemistry laboratory, it is what the food is made of that counts. It turns out that there are over 40 nutrients, but the three most important food materials are carbohydrates, fat, and protein. Other nutrients include vitamins, minerals, and fiber.

### Carbohydrates

Carbohydrates supply energy to the body. Simple carbohydrates such as blood sugar, milk sugar, or table sugar can be used quickly by the body. Starch from potatoes or bread is more complex. While the human body just breaks complex carbohydrates into simple sugars, many experts prefer foods rich in starches to foods rich in simple sugars for most diets. In part, this is because foods rich in starches tend to have more nutrients such as fiber, vitamins, and minerals than foods such as candy.

Many Americans may not be eating enough carbohydrates. The average person in the United States gets about 46% of the calories in his or her diet from carbohydrates while 55% has been recommended. This means more pasta, bread, and potatoes. A possible benefit from increasing your intake of carbohydrates and cutting down on fat is that you may find a slight increase in muscle mass. However, it is not a big effect.

### Fats and oils

Most of the calories in many common foods come from fat because a little bit of fat has a lot of energy. Many foods have over half of their calories coming from fat. These high-fat foods include butter (that is almost all fat), chocolate chips, potato chips, eggs, peanuts, hot dogs, coconut, avocado, and olives.

Both fats and oils are made from one part glycerin (also called glycerol because it is an alcohol) and three parts fatty acids. The glycerin is combined with the fatty acids to form an ester called a glyceride or a triglyceride. Fats are solid at room temperature while oils are liquid. The types of fatty acids used to make the fat or oil determine its properties. It is the fatty acid portion that makes the fat unsaturated or not.

Medical workers often call fats and oils "triglycerides." By using this name, they do not have to determine whether a fatty ester discovered in a blood sample would normally be an oil or a fat. Of course, the name is also four times longer than "fat" and, therefore, sounds more impressive.

Most people think that unsaturated oils are healthier than saturated, solid fats. The solid fats tend to clog veins and arteries such as those around the heart.

The average American eats 80 to 100 grams of fat per day. That is about one stick of butter per day. Many dietitians suggest cutting down on fats from food and switching to oils when possible.

## Cholesterol

Cholesterol is not a fat. While fats are triglycerides (esters composed of fatty acids and glycerol), cholesterol is not an ester at all — rather, it is a steroid. However, both fats and cholesterol are classified as lipids. A lipid is a natural organic chemical that dissolves in oil but not in water.

Cholesterol is found all over the human body and is produced in the liver. Much of it can be found inside cell membranes. It provides strength to the membranes and assists in some life processes. Even so, an excess of cholesterol in the blood can clog blood vessels. Clogged blood vessels tend to increase the risk of heart disease.

Polyunsaturated fats from vegetable oils and fish seem to help. Diets rich in these materials (such as those in Japan) reduce the incidence of heart disease for those people at risk. If your family has a history of heart disease, you might consider going to a doctor to go on a special diet. Also, doctors have drugs to reduce cholesterol levels. A little prevention might save a medical bill for heart surgery.

Some foods such as shrimp and lobster are rich in cholesterol but not high in fat. For most people, eating lobster rich in cholesterol does not raise their cholesterol level any more than a high-fat meal. The liver converts fat into cholesterol while the lobster just saves the liver some work. A low-cholesterol diet may not reduce someone's cholesterol level unless fat is also reduced.

### Protein

Protein is among the most useful of nutrients for humans. When digested, it can be used to build tissue or generate enzymes. Enzymes control which chemical reactions take place in the body.

Proteins are made of combinations of about 20 different amino acids. Of these amino acids, nine are recognized as "essential." These essential amino acids cannot be made by the human body and must be taken in as food. A deficiency in protein can cause any of several diseases. The exact nature of the disease depends on the type of protein that is missing.

Mixtures of proteins seem to be better than just high-protein foods. For example, a mixture of beans and meat seems to be a better source of protein than either the meat or beans alone.

Mixing vegetable protein sources is even more important. A particular type of bean may only supply five of the nine essential amino acids. For a complete meal of protein, it may be necessary to mix those beans with rice or pasta that can supply the missing amino acids.

On the downside, too much protein can add extra weight to your body, interfere with the absorption of minerals such as calcium, and even cause kidney damage. The fact that most Americans eat more protein than their recommended daily allowance (RDA) may explain the widespread problems with kidneys in this country.

## Food Energy

Carbohydrates are often quickly converted into energy (although an excess of them can be stored). Fat is slower to convert to energy. Except in the case of starvation, proteins are usually used for building tissue and running the body, but are not burned to make energy. Water has no energy value.

Humans store energy as carbohydrates (such as glycogen), proteins, and as fats (such as love handles or spare tires). Of these three major methods, most of the body's energy is stored as fats. Fat can store about 4,000 food calories per pound while carbohydrates store about 2,000 food calories per pound and proteins store about 2,500 food calories per pound.

### Fasting

The human body can go for days without food, but fasting for weeks is not healthy. The body needs food for energy and to repair body tissue. If the body does not get food, it will begin to convert body tissue into energy — even if that body tissue is heart muscle. Lack of food can be a slow, weak death. Of course, most people in the United States are lucky enough to avoid starvation.

### Diet in children

Children need three times as many calories as adults per pound of body mass. Thus, a child weighing 50 pounds would eat as much food as a woman weighing 150 pounds. This higher rate of metabolizing food is why the food bills for families with teenagers are so high. Those families blessed (cursed?) with teenagers will want to use many of the money-saving tips in this chapter and the first chapter ("Saving Time and Money through Chemistry").

## Minerals

Many minerals are needed by the body. Minerals are elements in chemicals that the body can digest. These minerals (elements) include: calcium, chromium, copper, fluoride, iodine, iron, magnesium, molybdenum, phosphorus, potassium, selenium, sodium, and zinc.

Calcium and phosphorus are needed for strong bones and teeth. Iron is needed for blood. Iodine is important for the regulation of growth. Sodium chloride (table salt) helps maintain body fluids. However, unless you perspire a lot, there is no reason to add salt tablets to your diet.

### Iron

Iron is used to produce red blood cells. The iron transports oxygen throughout the body inside of a material called "hemoglobin." Low iron levels (common to young women) can cause insomnia, tiredness, reduced short-term memory, and shorter attention spans. However, check with your doctor before using iron supplements because some people have a genetic defect that can cause an overdose of iron.

Good sources of iron include: red meat, clams, Cream of Wheat, tofu, tomato juice, and raisins. The RDA is 10 to 15 milligrams with women needing 15 milligrams daily. Menstruating or pregnant women

need extra iron. Note that iron supplements made for adults can be lethal for small children.

### Calcium

Calcium is used to form strong bones and teeth. It is important to get enough of it when you are young because it is not absorbed as quickly over the age of 40. Women in particular must consume enough calcium before menopause. This is because menopause reduces levels of estrogen that is needed for the body's absorption of calcium. A lack of calcium can result in osteoporosis and bones too weak to walk. (Vitamin D helps the body use the calcium. A diet rich in both calcium and vitamin D is needed to reduce the chance of osteoporosis.)

Other benefits of normal calcium levels include: fewer problems with high blood pressure, less chance for colon cancer, a smaller chance of premature births, and reduced menstrual symptoms. A daily intake of 1,200 to 1,500 mg can provide these benefits. Besides supplements, good sources of calcium include: milk (302 mg/cup), sardines (45 mg/each), cheese (180 mg/oz), salmon, tofu, and figs. Do not take any supplements if you have kidney stones.

## Vitamins

Vitamins are chemicals needed in a human diet that are not carbohydrates, fats, proteins, or minerals. For example, B-complex vitamins help certain enzymes. Vitamin C helps form the tissue that holds the body together. If a body gets too little vitamin C, the body literally falls apart. British sailors used to drink citrus juices such as lime juice to avoid this problem.

Proteins and carbohydrates are torn apart and reassembled in the human body to make usable chemicals. However, the body uses vitamins directly from food.

There are 11 essential vitamins with Recommended Dietary Allowances (RDAs). They include vitamin A; six B vitamins such as $B_1$ (thiamin), $B_2$ (riboflavin), $B_6$, $B_{12}$, folate, and niacin; vitamin C; vitamin D; vitamin E; and vitamin K. Less is known about biotin and pantothenate, and so RDAs have not been determined for those essential vitamins.

It is harder to overdose on water-soluble vitamins because they are quickly excreted from the body. Oil-soluble vitamins are stored in the body's fat. (Animals also store oil-soluble vitamins in fat. For that reason,

animal fat tends to be a good source of these vitamins.) The fat-soluble vitamins include vitamins A, D, E, and K. The water-soluble vitamins include $B_6$, $B_{12}$, C, biotin, folate, niacin, pantothenate, riboflavin, and thiamin.

While it takes more to overdose from the water-soluble vitamins, it is generally true that too much of anything can be toxic. Taking more than ten times the RDA of any water-soluble vitamin may cause problems. Of course, fat-soluble vitamins should be taken in lower doses because those vitamins will build up in fat.

As is the case with most chemical names, vitamin names make little sense outside a class in science history. The reader should note that a sensible way to name the vitamins would start with the letter A and go to Z before switching to A1, B1, and so forth. An even better way would be to number all the essential nutrients of the human body in the same way that the basic elements are numbered.

Instead, vitamins start with vitamin A and go through $B_1$, $B_2$, $B_6$, $B_{12}$, C, D, E, H (from the German word for skin), K (from the Scandinavian word for blood clotting), and so on. It seems that the biggest problem that most chemists face is what to call a chemical. It makes you wonder how they name their children!

In more advanced chemistry books, the authors draw pictures of the chemicals to help the readers. Readers often need these pictures because the names for the chemicals are either more than 40 letters long or have no meaning. (What on earth does "hirsutic acid" mean? Maybe that this acid is found in hair? It would be hard to guess that this chemical is found in a fungus and is a type of antibiotic.)

## The Science of Nutrition

James Lind in 1752 was the first to discover that the lack of fresh fruit and vegetables causes an ugly disease called "scurvy." It turns out that the lack of vitamin C in a diet causes human bodies to slowly fall apart. This was the start of modern nutrition.

### Eating a variety of foods

There are more than 40 essential nutrients — including proteins, fats, carbohydrates, vitamins, and minerals. No one type of food (including milk) can supply all these nutrients. This is the main reason to eat a variety of foods. It is often better to eat a plate of vegetables and a bag of pork

rinds than to eat two plates of vegetables. Eat too many salads and your body will crave meat.

Dietitians have divided foods into groups with similar nutrients. For example, cakes, brownies, and bread are made mostly of flour. All of these foods fall into the bread group. It is well known that humans can not live on bread alone. A diet of bread, fruits, vegetables, meat, beans, water, and dairy foods provides a wide range of nutrients.

The old diet plan was four servings of the bread group, two servings of the dairy group for adults (three or four for children), two servings of the meat and bean group, and four servings of the fruit and vegetable group per day.

The old food groups have been regrouped into the bread, cereal, rice, and pasta group (6-11 servings per day); the vegetable group (3-5 servings a day); a fruit group (2-4 servings per day); the milk, yogurt, and cheese group (2-3 servings per day); the meat, poultry, fish, beans, eggs, and nut group (2-3 servings per day); and the fats, oils, and sweets group (use sparingly). Except for athletes, very few people will be able to eat that much food.

### Vitamins from fruits and vegetables

With the rapid growth of the science of nutrition, it is easy to forget that we still know very little about the subject. This was demonstrated by a couple of recent studies in two reputable journals.

First, a study published in the *New England Journal of Medicine* (April 14, 1994) found that supplements of vitamin E and beta carotene (a source of vitamin A for the human body) produced no observable benefits. This result suggests that the benefits from vitamins A and E may have been exaggerated in earlier studies. Still, the journal was careful to caution readers not to accept this study as the final word on the subject.

Second, an article by Joseph Hotchkiss in the *Journal of Agricultural and Food Chemistry* found that vitamin C is not as important an antioxidant in tomatoes as previously thought. The plants need protection against sunlight and oxygen from the air. Scientists thought that vitamin C protected the plant. However, this study found that other chemicals including coumaric acid and chlorogenic acid may be just as important for this purpose as vitamin C.

These results suggest that other chemicals besides vitamin C in fruits and vegetables may be the ones that prevent cancer. It is not clear

how long cancer can be prevented, and as new studies are done, it is hard to guess which chemicals will be shown to have what benefits.

### Vitamin C as an additive

You may wonder why vitamin C is added to apple juice. Perhaps you guessed that it improves the nutrition of the juice. Actually, that is only part of the reason. Vitamin C is an antioxidant that helps protect the juice from oxygen in the air. At the same time, the drink is made more nutritious and the storage life is lengthened. (Note that vitamin C is needed by the body whether or not it prevents cancer. Avoiding vitamin C will cause scurvy.)

### Fruits versus vegetables

Fruits usually have fewer nutrients than most vegetables. Except for vitamin C found in citrus fruits, vegetables are richer in both vitamins and minerals. Of course, fruits taste better and provide more quick energy. They were once used as rewards much as candy is today. Perhaps the old ways were sometimes better.

### The theory of broccoli

Good nutrition requires the eating of food. This may sound simple, but trying to get most kids to eat broccoli is not so simple. Food must look, smell, and taste appealing for people to want to eat it.

When kids become older, they are more likely to enjoy broccoli if it is prepared in a tasty way. This is good because broccoli may help prevent some types of cancer. It contains several chemicals (with names that range from seven to twenty letters long) that help to prevent breast cancer and cancer of the pancreas.

### Proposed changes in the RDA

The Food & Nutrition Board of the Institute of Medicine that is part of the National Academy of Sciences is considering changes to its Recommended Dietary Allowances (RDAs). The old RDA may change into three levels: a deficient level, an average level for the nutrient, and an upper level that is considered safe. Also, the Food & Nutrition Board is considering different RDAs for different ages and ethnic groups. Stay tuned... .

## Pure Foods

Many makers of food would like to mislead buyers into believing that their food is "pure." To a chemist, such talk is nonsense. Except for a few ingredients such as sugar, salt, and water, most foods are complex mixtures of hundreds or thousands of chemicals. In many cases, these mixtures are actually more nutritious than if the food was carefully purified to give one chemical.

For example, ham is actually a mixture of hundreds of chemicals. By itself, the scent of cured ham is made of more than 100 different chemicals — all with imposing names such "propanone." As the curing process progresses, ham gives off more chemicals. At what point does the ham become impure?

This is a silly question because the ham was never pure. To a chemist, a food is pure only if it cannot be divided by physical means into chemicals with different properties. If a chemist can grind up a food, dissolve it in water and oil, and produce two vials that have different smells or colors, then the food was not chemically pure. Only a handful of foods can meet this test.

Foods such as beer, orange juice, any type of meat, any type of vegetable, and dairy foods are not pure according to this method. While these foods are still very good to eat, claims that the foods are pure should not be taken literally. Usually what is meant is that the foods will not kill most people unless they happen to be allergic to the food.

## Bread

Bread and cereals are an important source of energy, complex carbohydrates, thiamin (vitamin $B_1$), iron, protein, and calcium. Much of the protein and fat in bread comes from gluten. Gluten is also responsible for the stickiness of dough and the rigidity of the bread after cooking. Usually, the harder the bread; the more protein inside the bread. Pasta tends to contain the most protein.

A common disagreement among those people who care about bread is whether white bread is better than whole-wheat bread. Bread made from whole-grain flour has more minerals, but also contains phytic acid and fiber that can make it harder for the body to absorb these minerals. Whole-wheat bread also contains more B-group vitamins, but it tends to spoil more easily.

Toasting makes the carbohydrates in the bread easier to digest, but toasting can also cause the loss of some of the bread's protein and vitamins.

## Oats

Among the cereal grains, oats have the highest amount of protein and are high in carbohydrates. This makes them quite nutritional, especially for young animals (or children!) who need the protein for the growth of tissue. As the commercial said, "Oatmeal, it is the right thing to do." (I have often wondered why the advertisers did not make that sentence read, "Oatmeal, the right food to eat.")

### Fiber

Fiber is just the part of food that is not digested. The body does not use fiber for energy or building body tissue. However, fiber may help fight diseases such as diabetes, constipation, gallstones, ulcers, colon cancer, and breast cancer.

To pack as much nutritional value into a food as possible, it used to be thought that indigestible parts of the food could be removed. However, it seems that even those parts of the food are not useless.

Fiber comes in two varieties: soluble and insoluble in water. Soluble fiber slows down the rate at which food is digested. Soluble fiber may also reduce cholesterol levels in the blood. Insoluble fiber lowers the amount of time that food spends in the body while adding some bulk to the stools.

Good sources for insoluble fiber include: wheat bran and the outsides of fruits, beans, and seeds. Coarse insoluble fiber can relieve constipation if mixed with water or milk. Soluble fiber can be found in oats, vegetables, and fruits.

Health effects such as lowering of blood cholesterol is why that actor said that eating oats was the right thing to do. Actually, you might want to eat wheat bran cereal with milk on days when you are constipated.

## Meat

One good reason to eat meat is that it promotes the humane treatment of animals. Farm animals lead cushy lives compared to life in the wild. They are on diets designed for rapid, healthy growth. Sometimes,

the animals are even cared for when they are sick. Contrast this life of leisure with mass starvations and diseases in the wild. So, do not feel bad when you are eating meat. Think of it as helping some poor creature with cute eyes.

To give you an idea of how rich in protein a vegetarian's diet must be, take a look at the composition of lean meat. It is about 75% water, 18% protein, 4% of miscellaneous materials (including minerals), and 3% fat. That is one heck of a lot of protein. There are a number of vegetables that are also high in protein (beans for example). Still, vegetarians must watch their diet closely.

### Meat tenderizers

Meat tenderizers can improve the flavor of many cuts of meat (except maybe filet mignon). These tenderizers are made of enzymes that partially break down the tissue holding the meat together. Filet mignon is already soft enough to eat. If you put tenderizer on it, you may have to use a spoon rather than a knife and fork.

## Beer

The brewing industry in the United States produces huge quantities of beer. In 1992, United States breweries produced almost 25 gallons per U.S. citizen — and most babies do not drink that much!

Although people are drinking less beer than in the past (!), breweries can still use large-scale methods such as huge vats and automated bottling. These methods help keep costs low and the quality predictable. Most of the major brands of beer are brewed in huge factories.

The main ingredients of beer are barley malt, grains (the seeds of certain grasses), hops (dried flowers of a vine plant), and water. Beer makers buy large shipments of grain, barley, and hops from farmers or commodity exchanges. Malt is made by soaking grain (usually barley) in water and causing the seeds to sprout. The baby plants are dried to become malt and sometimes powdered. Malt is rich in various enzymes such as diastase that can quickly convert starch into sugar.

(Note that powdered malt is sometimes sprinkled into milk to create malted milk. The enzymes from malt can help people with digestion problems.)

However, the key ingredient of beer is water — although a case could be made for alcohol. Good beer is mostly water, and water is needed

in the factory to heat and cool the beer. For every gallon of beer, the brewery uses ten gallons of water.

All the ingredients are thrown into a large vat, and yeast feed on the carbohydrates from the grain. Yeast can change sugars and starches into ethyl alcohol. This process is called "fermentation." When a desired level of alcohol is reached, the beer is purified, canned or bottled, and heat-treated to kill germs.

One large brewery avoids heat treatments by using special filters. Germs are much bigger than most chemicals. The germs are trapped on the filters while the rest of the beer goes through the filters' pores. Some people prefer the taste of beer that has never been exposed to heat. Heat can cause a series of chemical reactions that produce different flavors in the beer. Filtering avoids these changes in flavor.

## Strong Beverages

Hard liquor usually starts with the fermentation of plant material. Each type of drink starts with its own mixture of vegetables such as potatoes, corn, rye, or barley. Yeast will eat many types of plants, but there is only a small market in the United States for drinks made from seaweed. (However, that may be an idea for some health food stores!)

A poor quality wine or beer is usually the result of the yeast fermentation. The yeast cannot bring the alcohol content of the mixture much above 20%. After a certain point the alcohol will begin to kill the yeast for the same reason that pure alcohol can be used to disinfect wounds.

To increase the alcohol content above 100 proof (50% alcohol), the crude mixture is boiled and droplets rich in alcohol are condensed (changed from a vapor into a liquid) in a process called "distillation." Most of the alcohol evaporates before the water and vegetable matter vaporize. By collecting drops from early in the distillation, the alcohol can be concentrated from about 20 proof to over 160 proof (80% alcohol).

Stainless steel or copper vats are often used for the distillation. The distillate (the condensed droplets) is placed in wooden barrels and aged to give the liquor its flavor. It is the barrels that give the drink most of its flavor. The length and quality of aging can make the difference between good and bad liquor. Wide temperature ranges while aging expands and contracts the barrels and brings more wood chemicals into the liquor.

The aged liquid from the barrels is diluted with water and sometimes sugar or honey is added. The quality of the water is important (just as with beer). Traces of metal in the water can ruin a liquor.

Alcohol is one area where saving money is not a big deal for most people. They are willing to pay a little extra because they consider it a luxury and not an everyday expense. Lawmakers have used this to raise taxes on alcohol.

### The measure called "proof"

Using the American system, whisky that is 160 proof is actually 80% grain alcohol. To find the percentage of alcohol, just divide the proof number in half. Alcohol of 100 proof is really 50% ethyl alcohol by volume. That is, 100-proof liquor is half pure alcohol and half flavored water. Using this system, gunpowder soaked with 114-proof liquor will ignite.

The British use this gunpowder test to set alcohol at 100 proof. Discerning beer and wine drinkers may notice the higher alcohol content of these imported drinks.

As you may have guessed from the gunpowder test, pure alcohol can catch fire. For that reason, do not smoke around liquors over 115 proof in the American system or 100 proof in the British system.

Alcohol absorbs water vapor from the air. Thus, 200-proof (pure) alcohol will slowly drop to 190 proof (95% pure) if left open on a humid day.

### Headaches from alcohol

Drinks such as beer, wine, and distilled spirits can cause migraine headaches. The chemistry is a little complex; but perhaps alcohol triggers a mild allergic reaction that releases histamine. Histamine reduces serotonin levels in the brain and causes a headache.

This would suggest taking an antihistamine to prevent the headache. Unfortunately, the antihistamine may interact with the alcohol to cause problems. Antihistamines and alcohol are both depressants. They could work together to knock someone out.

A possible way to stop the headaches is eating some sugar before drinking alcohol. Sugar often increases serotonin levels and may counteract the histamine.

### Denaturing alcohol

Grain alcohol is sometimes made toxic for tax reasons. By adding some methanol (wood alcohol), drinkers often suffer blindness because most livers change the methanol into formaldehyde. This is a little like putting poison on a child's thumb to wean the child from sucking his or her thumb (not a good idea). A substance has been found that is so bitter it makes alcohol undrinkable without causing blindness. Even so, lots of alcohol are still spiked with methanol.

In any case, check the label. The label will have something like "denatured alcohol," "poison," or "toxic" on it. In its list of ingredients you should be able to find something like "S.D.A. Alcohol 1 (8%)." In English, this means that the product contains ethyl alcohol, but that it is "specially denatured alcohol." The number after alcohol shows the method used to render it undrinkable.

There are around 60 approved methods to denature alcohol. In the example above, method number 1 was used. Method 1 involves adding methanol to cause blindness.

Other methods are used when denatured alcohol needs to be free of methanol. For example, method 40 involves adding a chemical called "brucine" and a little tert-butyl alcohol. Again, these chemicals make the alcohol less appealing to drink.

The number in parentheses is the percentage of ethyl alcohol in the product. This is half the size of the number for proof. Therefore, a mouthwash that is 8% alcohol is 16 proof.

Mouthwashes often use non-denatured alcohol as one of the solvents. However, most people would prefer to drink other liquors. A fresh, mint flavor is an acquired taste.

## Food Poisoning

Some types of food impurities can cause sickness or death. A few examples of this can be found in this section.

### Poison mushrooms

One hobby that can give you food to eat at the end of the day is mushroom hunting. Unlike deer or fish, mushrooms can not run or swim away. Still, if anything, the mushroom hunter must be more careful.

Mushrooms do not like being eaten and some contain deadly poisons to protect themselves.

## Honey

Honey is a type of invert sugar made by bees. However, honey is far from pure. Bees leave traces of pollen in the honey. (Pollen is a material needed to form plant seeds.) This pollen can cause allergic reactions in some people. The pollen from some plants can even be poisonous.

For example, an army of Greeks was intoxicated by honey back in 400 BC because the bees had been gathering the nectar from rhododendrons. Even today, people sometimes become ill by eating honey.

## Toxins from potatoes

Thousands of cases of poisoning from bruised or green potatoes have been reported. This danger is especially great for pregnant or soon-to-be-pregnant women because the toxins can kill fetuses (unborn children). The problem comes from a class of chemicals called glycoalkaloids. Strangely, these chemicals are far more deadly in humans than in other animals. Maybe the potatoes are defending themselves?

## Cancer from food

The current method of testing whether a chemical causes cancer is under attack. Too many chemicals test positive. For what it is worth, scientists at the Food and Drug Administration found that food itself accounts for 98.8% of the cancer risk from food. When the risk of natural spices is added, only 0.2% is due to man-made additives.

## Aflatoxin

Natural food is not always better for people than food from a chemistry lab. A widely quoted example of this is the unwanted food additive called “aflatoxin.” It is often found in foods such as nuts, corn, rice, wheat, and peanut butter. A fungus produces this potent cancer-causing chemical. Without a fungicide protecting the food, it will often be formed.

## Food Containers

With a few exceptions, the trend in food packaging has been away from older materials such as metal, glass, and paper. Plastics (also called "polymers") are used in much of the new packaging.

While glass is still useful when a strong, brittle, translucent (lets light shine through) material is needed, plastics can be tailored to most other tasks. In many cases, glass is too fragile and rigid. For example, a major cleanup job used to be required every time somebody dropped an old soda pop bottle. Besides mopping up the liquid to avoid a sticky floor, the pieces of glass might cut bare feet in the kitchen or a tire on the road.

Polyethylene terephthalate (PET) has been rapidly replacing glass for many purposes. PET will not shatter like glass. It is also lightweight, translucent, somewhat heat-stable, easy to bend, and can be recycled. Because of these properties, PET has become very popular for soda pop bottles. About 2.1 billion pounds per year of PET are produced.

Likewise, paper or paper coated with wax are good for some purposes, but modern plastics are replacing paper in many tasks. For example, polystyrene foam is a good insulator of heat that can slow the transfer of heat through a container. Many polystyrene containers are such good insulators that they can be used to kept hot coffee hot or cold drinks cold. In contrast, waxed paper lets heat transfer through the container so that the food quickly becomes room temperature.

### Kosher packaging

For those people of the Jewish religion, some plastics are now officially kosher. Of course, this does not mean that you should eat the plastics! Instead, it is now OK to buy kosher food wrapped in these plastics.

Some Jewish leaders were concerned that additives made from animal fats would work their way from plastic wraps into the food. This sort of made sense in a way. It is true that many plastics use salts of fatty acids such as calcium stearate to make the plastics more flexible. Stearic acid is a type of fatty acid often found in animal fats such as beef fat. Calcium stearate is just the calcium salt of the acid.

When it is put into a plastic, calcium stearate acts as a plasticizer to lubricate the inside of the plastic and help the plastic bend. (Plasticizers also help keep vinyl soft.) While flexible plastics are nice for food

packages, the use of plasticizers from animal fat created a religious problem for some Jews, some Muslim groups, and some vegetarians.

To solve this problem, Solvay Polymers made salts of stearic acid that come from vegetable sources rather than animal fat sources. These fatty acid salts from vegetables can be used in place of the other fatty acid salts. Just like a trained chemist, the plastics cannot tell the difference.

### Advantages of plastic wrap

Plastic films such as Saran wrap have some advantages over paper. The films are transparent (no guessing at what is in the bag), lightweight, puncture-resistant, free of odors and flavors, nontoxic, and transmit moisture very slowly. By using these wraps and bags, food stays moist in a refrigerator or freezer for a long time. Also, you can store dead skunk next to Limburger cheese with no mixing of flavors.

### Aluminum foil

Aluminum foil can also be good for wrapping. It is mostly aluminum metal with a thin coat of aluminum oxide to protect it from water. It can withstand both very low and very high temperatures. It conducts heat well — making it good for cooking or freezing. Like plastic wrap, it seals in odors, flavors, and moisture.

Aluminum gives off sparks (called “arcing”) when foil untreated with a special plastic coating is placed in a microwave oven. Also, foods with high pH (basic) or very low pH (acidic) can dissolve aluminum. The term for materials that can react with either acids or bases is “amphoteric.” Foods with a sour taste (low pH) may be more safely stored in plastic wrap.

Aluminum is not ferromagnetic like iron. In the early 1960s opening a can of frozen orange juice was an unwelcome chore. At the time, the cans had aluminum ends. When the can opener was finished, the lid would fall into the can and was sometimes difficult to fish out. With modern cans that is no longer a problem. (Long live technology!) The canneries ran into trouble because the magnet on automatic can openers would not grab the lid as it does lids made of steel.

## Freezing and Refrigerating

Refrigeration slows the growth of germs. It also slows chemical reactions such as oxidation that can make food smelly or toxic. Freezing

food not only slows the growth of microorganisms because of the cold but also removes the water that the germs need to live. Freezing is a good method for long-term food storage.

### Freezer burn

Freezer burn is caused by loss of water from frozen food. Even at very cold temperatures, water can go from the solid phase (called ice) into the gas phase (called water vapor). This process is called sublimation. Unprotected foods will lose water in this way from exposed surfaces. Aluminum foil or plastic freezer bags can slow the loss of moisture in the freezer.

The loss of moisture that causes freezer burn makes it easier for the food to react with oxygen in the air. For this reason, the surface of the food is often the most damaged part. Try cutting into the food. You may find that the freezer burn can be cut away and the center of the food salvaged.

### Refrigerator and freezer temperatures

The temperature setting on refrigerators and freezers is a compromise between energy costs and costs from food spoilage. If the freezer is set just four degrees Fahrenheit (F) too low, it increases the cost of refrigeration by 10%. A freezer setting of 0 F should be OK while 34 to 37 F is a good range for the refrigerator. (Of course, the refrigerator should be above 32 F as water would start to freeze below that!)

Almost all toxin-producing germs are in a dormant state at 32-38 F. If you make sure your refrigerator is in this range, it will reduce your chances of food poisoning as well as make your food last longer.

### Frozen dinners

Frozen dinners usually cost less than a restaurant meal and require little time to prepare. They are as nutritional as most home cooked meals. These packaged dinners are a good way to avoid cooking and cleaning dishes. Married couples can even cook together. The wife can pick out the dinner, the husband takes it out of the box, the wife removes the foil from the dessert, the husband pokes holes in the rest of the foil, and the wife can put it in the oven.

You must follow the instructions on the package exactly. If you cook the food too long, the color and texture of the food will go bad on you.

## Other Methods of Preserving Food

### Irradiation

Irradiation is the use of high-energy emissions from radioactive sources. Sealed containers of food can be sterilized using this technique. The amount of radiation can be carefully controlled to kill insects, molds, or bacteria. The energy of the radiation is set at a low enough level so that the food does not become radioactive.

Still, irradiation has had its share of problems. Bacteria sometime enter the package after being treated (really a problem with the package). Oxygen in the package can react with the food after its treatment to spoil the food. Also, Clostridium botulinum often survives radiation to cause botulism. Note that this germ also causes problems for pasteurization (heat-treating food). Check irradiated food carefully before buying or eating it.

### Dried food

By drying food, the moisture needed for the growth of microorganisms is removed. The key to preserving the food is to keep it dry. So, if your trail rations get wet, be sure to either eat them quickly or dispose of them.

Dried food can taste very good and often does not require refrigeration. However, dieters should be aware of how dried food is made. A regular bit of food — such as a grape or a sliver of meat — has the water removed from it. Water has no calories. All the calories of the original food are still in the much smaller and lighter dried food. A pound of dried meat has far more calories than a pound of meat directly from a cow.

### Natural food preservatives

Some foods such as red raspberries and strawberries are best stored packed closely together and in an air-tight container. These berries give off chemicals to slow the growth of fungi.

Many other living things also make chemicals to fight off natural predators. These chemicals are usually "secondary metabolites" — meaning, chemicals produced by the life form not directly needed for life processes. Most of the pesticides in plants are of this type.

### Chemical preservatives

Many of the preservatives added to food either slow the growth of germs or protect the food against oxidation. Various acids, salts, and sugar have been used to slow the growth of germs. BHT and BHA along with vitamins such as A, C, and E are antioxidants. Antioxidants work by reacting with oxygen before it can react with the food.

## Miscellaneous Topics

### Caffeine extraction

Americans average 211 mg/day of caffeine (about seven-thousandths of an ounce). The caffeine comes from coffee at about 60-200 mg/cup, cocoa at 5 mg/cup, chocolate at 6 mg/oz, cola at 35-55 mg/can, and tea at 30-50 mg/cup. Only about 17% of the average American's daily intake of caffeine is from soft drinks. Most of the caffeine is from coffee.

While most Americans consume caffeine every day, many people are trying to reduce their intake of caffeine. Others wish to avoid caffeine around bedtime. In both cases, decaffeinated coffee and caffeine-free colas can quench a thirst without creating a caffeine "buzz."

Because coffee beans are rich in caffeine, "extraction" is used to remove (extract) the caffeine from the beans. The extracted caffeine can then be put into soft drinks and alertness pills.

Extraction requires water and an oily solvent. Trichlorethane is often used as the oily solvent for extracting caffeine out of coffee. However, carbon dioxide shows some promise as a solvent for this technique.

Carbon dioxide is normally found as a gas that comes from the burning of organic materials. Living creatures exhale it when they are burning energy. Also, this gas makes soda water bubbly.

At very low temperatures the gas becomes a solid called "dry ice" that is used to keep things very cold. At atmospheric pressure, carbon dioxide never becomes a liquid. It goes directly from being a solid to becoming a gas in a process called "sublimation." The reason that solid carbon dioxide is called "dry ice" is that it disappears without leaving a liquid behind.

However, it can become a liquid at pressures greater than five atmospheres (five times the pressure at sea level). This type of carbon dioxide is called "liquid carbon dioxide."

A major use of this type of carbon dioxide is to dissolve organic materials from a mixture. It can be used to decaffeinate coffee, extract the nicotine from tobacco, and remove the bitterness from hops. The liquid carbon dioxide (which can be at room temperature under pressure) is added to the mixture to be extracted. The carbon dioxide has oil-like properties. Therefore, the oils dissolve into the carbon dioxide. When the carbon dioxide is drained away, it takes many oily materials with it.

Carbon dioxide is preferred over other solvents because no trace of it remains after the extraction. At atmospheric pressure the liquid carbon dioxide turns into a gas and bubbles out of the watery solution. If a decaffeinated drink does not taste like the real thing, it is probably not because of leftover solvent. It may be because other oily compounds besides the caffeine were also removed during the extraction.

A variation of this process is to warm carbon dioxide above 82 degrees Fahrenheit and increase the pressure above 73 atmospheres. This type of carbon dioxide is called "supercritical carbon dioxide" and is somewhere between a gas and a liquid.

Supercritical carbon dioxide is a good solvent much like liquid carbon dioxide and can be used for the same purposes. Also, it is used to extract oil out of oilseeds such as soybeans or sunflower seeds. Again, supercritical carbon dioxide has oily properties that can dissolve oils while leaving water behind.

### Cod liver oil

Cod liver oil may bring back some memories to older readers. This stuff was supposed to be good for you, but was not very pleasant.

In the 1840s, two publications came out that claimed cod liver oil was helpful in treating some types of gout, rheumatism, and pulmonary consumption. Even today, doctors argue over whether cod liver oil can treat tubercular diseases.

A foul-tasting variety of cod liver oil has been used as a folk remedy for arthritis and gout for centuries in Norway, Iceland, and Scotland. Modern chemistry (1840s) improved the taste. Before, it was dark, smelly, and foul tasting. Now, it is tasteless.

As the name suggests, it is a fish product. The makers of the oil cut the livers out of cod (a type of fish). They gently heat the livers and extract out the organic chemicals from the organs. The mixture of chemicals in the oil is complex. No one is really sure how it works. Still, with centuries of folk medicine behind it and two scientific papers, there may be something to it.

## Gas production during digestion

Some sugars cannot be digested by people but are favorite foods of bacteria in the human gut. As a result, a lot of gas is produced after a meal including foods such as baked beans.

A method to direct the gases upward in the body (rather than the usual direction) is to eat such spices as ginger, cinnamon, or peppermint. They loosen the sphincter muscle and allow the gas produced by the germs in the gut to pass out the nose and mouth.

Another way to approach this problem is eating an enzyme that breaks down sugars into a form that humans can digest. A product called Beano can be taken in tablet or drop form and reduces the quantity of indigestible sugars in many foods.

## Ice cream substitutes

About 10% of Americans suffer from lactose intolerance to the point where they need special medicine to eat ice cream. Lactose is a type of sugar found in milk and ice cream, but some people lack the enzyme to digest it. Nondairy products such as tofu (which comes from bean curds) or sorbet (which is mostly fruit) do not contain lactose. Thus, these foods can be eaten by people with lactose intolerance.

# Chapter 5

# An Introduction to Health Chemistry

## Do-It-Yourself Medicine

All serious illnesses need care from a doctor. However, minor problems, such as small cuts and mild colds, can often be treated without a doctor. Home remedies can save money and avoid trips to the doctor's office. (Do doctors make house calls anymore?) Still, as with any other do-it-yourself project, expect that it will take more work than relying on a pro. Also, you will make mistakes.

Some of the mistakes are subtle and based on chemistry. For example, some home cures require the drinking of oils such as mineral oil or cod liver oil. After taking the oil for a while, you may develop problems such as rickets, night blindness, and slower blood clotting. You will probably have no clue why these problems are happening and see a doctor because of it.

A good doctor will ask if you are taking any home remedies. When the doctor discovers that you are drinking an oil, the solution to the new problems will appear simple to him or her. Most doctors know that oils dissolve the vitamins stored in body fat. Oils can drain the body of vitamins A, D, K, and E and cause the symptoms of a vitamin deficiency. Note that all four of these vitamins are fat-soluble. (By the way, cod liver oil is not as bad as mineral oil because fish oils are rich in vitamins A and D. However, problems with vitamins K (blood clotting) and E (immune system) can still occur.)

To a doctor, the cause of the problem is simple because the doctor has either seen the problem before or read about it. However, the do-it-yourselfer may not foresee problems like this with home remedies.

### Read the label

While labels tend to be longer now than ever before, it is still important to read them. A magnifying lens seems to help. The labels tell you a significant portion of what has been learned about the product since it first came out. Reading the label will help you avoid the mistakes of other users.

One problem with reading labels is that a single medicine may have many names. The more widely used a chemical becomes; the more names it acquires. The most widely used chemical — water — has many names in every language (ice, water, snow, steam, and so on). Even more recent chemicals can acquire hundreds of names.

Every drug has a "generic" name, but many drug makers will invent their own name for the drug. For example, one drug has a generic name of "Amitriptyline" but has also been called Tryptanol, Laroxyl, and Endep (among other things). Notice that the drug maker's names are easier to remember than the generic name. They want to establish their brand name as a reliable, high-quality source of the medicine.

### Units of medicine

Besides the usual measures of mass such as milligrams (mg) and measures of volume such as cubic centimeters (cc), many drugs from biological sources use the "units" system. Drugs such as insulin can vary in strength from batch to batch. These units measure the relative strength of the batches.

If the bottle of insulin says "U 100," this means that one cc from that bottle contains 100 units of insulin. If the bottle says "U 40," one cc would only contain 40 units of insulin. For a diabetic who needs 100 units once a day, using the bottle of U 100 would mean injections of one cc instead of 2.5 cc from the bottle of weaker strength (U 40).

It is often better to inject small quantities of fluid. Less injected liquid means fewer problems caused by excess fluid at the injection site. Strong batches of insulin (U 100 or more) can reduce the volume of fluid in the syringe. Of course, very small volumes can be hard to measure accurately.

## Aspirin

Aspirin is one of the most useful man-made drugs. Since it was first created in 1899, billions of people have tried it. It is used as an analgesic (pain-reducer), antipyretic (fever-reducer), and anti-inflammatory (reduces painful swelling). Overall, aspirin is also one of the safest drugs.

Still, aspirin can cause problems if abused. For example, small children running high fevers can develop Reye syndrome if given aspirin. Also, it can cause stomach bleeding — especially in large dosages such as two tablets.

This second problem can be helped with a little acid-base chemistry. One of the names for aspirin gives a clue about its chemistry: "Acetylsalicylic acid." While most of the name does not mean much even to a chemist (What does "Kenneth" mean to you?), the last part tells a chemist a lot about this drug.

The word "acid" means aspirin is the type of chemical that dissolves in basic (high pH) solutions of water. Acids dissolve in high pH solutions because they react with bases to form salts that tend to be soluble in water. Aspirin itself is more soluble in fats than in water.

Aspirin goes into the stomach soon after it is swallowed. In the acidic solution of digestive juices, it stays in the acid form and can pass through the fatty walls of the stomach. In going through the walls, it sometimes causes bleeding and stomach pain. Once into the more basic bloodstream (roughly pH 7.4 with pH 7 being neutral), it becomes a salt and water-soluble.

The way aspirin changes from an acid into a salt provides a method for reducing stomach upset. A salt is formed by dissolving aspirin in a basic water solution. Next, the water is evaporated to leave behind the salt. When this salt touches water again, it dissolves and is easy to drink. In the acidic stomach, the salt becomes aspirin again. However, instead of large tablets that might cause bleeding, the aspirin becomes tiny crystals that cause fewer problems.

Another way to reduce stomach upset is to coat the aspirin so that it passes through the stomach without being absorbed. These coated tablets take longer to work.

### Cold packs

Applying a cold pack will often reduce the swelling of an injury and make it less painful. While kissing the injury may be nice, cold is better at soothing hurt nerves.

Ice packs are often the cheapest way of applying cold. Just take a thick plastic pouch, fill it with ice, and apply it to the sore area. An ice pack works because it requires heat for the ice to melt. Heat from the sore area goes into the ice pack to melt some ice. With heat going into the ice pack, the skin temperature around the sore area goes down.

A process such as melting ice that requires heat is called "endothermic." This is the opposite of a process such as fire that gives off heat. Processes that give off heat are called "exothermic."

Melting ice is not the only endothermic process that can be used for cold packs. Because ice tends to melt at room temperature, cold packs that use ice need a freezer nearby. In remote locations, endothermic chemical reactions can provide the cooling instead of ice.

Cold packs that do not use ice commonly work by wetting some ammonium nitrate with water. As this salt dissolves in the water, the bag with the salt solution takes heat from its surroundings. If the sore area is next to the bag, the heat from the sore area will go into the bag. While other reactions are possible, melting ice and dissolving ammonium nitrate are the most convenient.

### Antiseptics

An antiseptic is a chemical that prevents the growth of germs. Perhaps the most common antiseptic is ethyl alcohol. When applied to the skin, it helps prevent infections in wounds, and as a bonus, it helps stop bleeding. A 70% solution of ethyl alcohol in water is a very good antiseptic. For reasons that are not clear, 140-proof spirits kill germs faster than pure alcohol. Isopropyl alcohol also kills germs but is more toxic.

Hexachlorophene is an antiseptic found in some soaps. By reading the label carefully, it is easy to discover if your brand of soap uses it. It can reduce the number and types of bacteria on skin. With fewer bacteria, the spread of diseases by handshakes is less likely. Also, cuts are less likely to become infected. However, this chemical is not to be used for washing infants. It is absorbed through the skin and can harm an infant if used regularly.

Saponated cresol is used in Lysol and Creolin as a disinfectant. It can be used on skin only in very dilute solutions.

Some antiseptics oxidize the areas they touch and destroy anaerobic bacteria (germs that do not breathe oxygen). Iodine tincture combines the antiseptic power of alcohol with oxidizing power of iodine. It can be used for small wounds but is not safe for large wounds. Iodine in glycerin is sometimes used to treat mucous membranes. (An example of a mucous membrane would be the part of the lip inside the mouth. This type of skin is called a mucous membrane because it is usually covered with a thin layer of slime called "mucus.")

The most powerful oxidizing agent used for an antiseptic is potassium permanganate. This chemical has a special place in the hearts of all chemists because it is used to clean glassware. It destroys most organic things on contact. As you can guess, it is used in very dilute solutions as an antiseptic.

The most widely used oxidizing antiseptic is hydrogen peroxide solution. Hydrogen peroxide turns into oxygen gas and water when it contacts flesh because of the rough edges and the presence of metals. (Even in the bottle it slowly decomposes. These bottles often give off oxygen gas.) The oxygen kills germs in a small wound. Also, the oxygen gas cleans the wound with its bubbling action.

Be sure to use the dilute 3% solution and to store it in a dark, cool place. A 90% solution of hydrogen peroxide can be used as rocket fuel!

## Diaper rash

Changing the diapers on a baby is not a thrilling task. However, it keeps the baby's skin free of urea from the baby's urine. Some bacteria will change urea into ammonia and cause diaper rash. While ammonia is good for washing floors, it can make skin red and irritated.

Washing cloth diapers is even less fun. The diapers not only have to be cleaned; they also have to be sterilized by chemicals (and perhaps sunlight). New mothers should consider how much their time is worth. Women busy with their own careers may find that their time is valuable enough to use a diaper service or use only disposables.

Full-time mothers may want to save money by cleaning their own diapers. This is not a simple task because a trace of detergent on a diaper that is not fully rinsed can lead to diaper rash. Also, a diaper not fully sterilized can contain bacteria that cause diaper rash.

The diapers may need to stay in sterilizing solution for about six hours. (Always follow the advice on the package.) The diapers must then be washed and thoroughly rinsed. If they can be dried in bright sunshine, it will help kill many of the bacteria.

Be sure to thoroughly wash after touching the sterilizing solution. It is usually quite toxic and can easily kill a baby.

## Alcohol

"Tolerance" is a word that brings to mind images of people of all races and creeds living in harmony. The chemical meaning of the term is not so far removed from the usual meaning, but there is a nasty catch.

Chemists use the term to describe how well the body can handle a chemical within it. A high tolerance means that a lot of the drug must be present before the body reacts to the drug. Regularly using a drug can create a tolerance for the drug. The catch is that the dosage required to kill does not change.

Thus, the person has to take more of the drug for it to have any effect, but each increase in dosage brings the person closer to an overdose. Alcohol is the most common drug where tolerance is a problem. If you find that you or any of your friends can do great feats of mental or manual dexterity while filled with lots of liquor, there is probably a serious drinking problem. (Also, from a financial point of view, it costs more and more to get drunk.)

### Drug interactions

If you take any medicines, check with your doctor about drinking alcohol. Think about what happens when aspirin is taken with scotch. The contents of the stomach are made more oil-like, and this helps oil-soluble aspirin to go through the stomach lining. As a result, the effect of aspirin is stronger and more rapid. Also, an overdose of aspirin is more likely.

Not every chemical is as safe as aspirin. Many drugs can travel through the lining of gut more quickly with the help of alcohol. Overdoses and death can result.

This is not the only interaction possible for alcohol. Both alcohol and barbiturates (a type of hypnotic once found in sleeping pills) are destroyed in the liver. Taking old-style sleeping pills and alcohol at the same time caused the barbiturates to stay in the body too long. The liver

would work on digesting the alcohol instead of the sleeping pills. The overdose of sleeping pills could be fatal.

If you have a good background in science, you can read about these interactions in a book called *The Physician's Desk Reference*. In general, be careful when mixing drugs and alcohol.

### Curing alcoholism

There is no easy way to cure a drunk. Actually, any habit is easy to fall back into. This is true whether the habit is waking up with the sunrise or drinking too much. Still, chemists can help sometimes if the person wants the help.

Chemists are working on anti-alcohol devices. An old approach was denaturing alcohol. There are now dozens of approved ways to poison alcohol.

One way to help a person quit is using a chemical such as disulfiram that makes alcohol hard to keep down. The drinker eats a little of the chemical. If some alcohol is consumed shortly after that, he or she will become nauseous. Unfortunately, this method is dangerous and has never worked very well.

A company from California is now working on a new drug that promises to make drinking much safer. It is called Detoxahol and works by speeding up the rate at which alcohol is metabolized by the body. The drug works remarkably well in mice — which should lower the number of rodents driving while drunk!

First, the rat is given a strong dose of alcohol. Then the rat is given a dose of Detoxahol that lets the rodent's small intestine digest the alcohol. Soon, the rat is fully sober and ready to drive home. The uses are obvious assuming that the Food and Drug Administration (FDA) approves it. However, the approval process is long and difficult. In the meantime, drunks are left with home remedies such as eating a banana or some sugar that simply do not work.

It normally takes eight hours to metabolize eight units of alcohol: eight cups of beer, eight glasses of wine, or eight shots of whisky. Until the alcohol is removed by the liver, the person cannot safely operate heavy machinery. This is the time to call a taxicab.

## Smoking

If smoking were to be invented today, it would never be allowed to be sold. The tar from burning tobacco causes cancer, and smoking is closely tied to lung cancer. The FDA would consider smoking to be unsafe.

Besides a shortened life span, smokers have to put up with the rising cost of cigarettes and other tobacco products. This is not due to rising costs of farming or producing the tobacco. Rather, the government has had good luck in raising revenue by taxing these products. Whatever the cause of the price increase, smoking has become an expensive habit.

In addition, smokers live with an increased risk of starting a fire. To enjoy tobacco smoke, the tobacco must be on fire. Unless the fire is carefully put out, it could spread to other combustible items such as a bed or a forest.

There is also a social disadvantage to smoking because it can act like a mood ring. The human body closely regulates the level of nicotine (the chemical that causes the smoker's high). Eating or stress can lower the level of nicotine to where the smoker goes into withdrawal, and he or she gets a powerful urge to smoke a cigarette. In a social setting, this is a better clue that the person is nervous than underarm sweat.

If you are a smoker, you should consider quitting. If you are a stubborn smoker who likes smoking, you should consider either switching to a brand rich in nicotine or using a chewing tobacco. It is the nicotine that produces the high while it is the tar that causes lung cancer. By smoking cigarettes rich in nicotine, it is possible to get the high while smoking fewer cigarettes and breathing less tar. With chewing tobacco, no cancer-causing tar goes into the lungs. Both habits are safer than smoking low-nicotine cigarettes.

### Quitting the smoking habit

No matter why a person wants to quit, smoking is a hard habit to break. Only 3% of those who try to quit smoking succeed after one year. Some smokers undergo a major surgery for lung cancer or heart disease and are told by their doctors to either quit or die. An amazing 50% of those people continue to risk their life by smoking.

The first hurdle is the physical addiction. Withdrawal starts within hours and lasts for a week or two while nicotine washes itself from the fat where it is stored. The physical urge to smoke is strong during this period

while the body tries to maintain its old level of nicotine. Symptoms include craving, anxiety, weight gain, insomnia, and a bad mood.

Even after the nicotine is out of the body, the smoker can still feel the need to hold a cigarette after eating or while driving. Habits are hard to break even without withdrawal symptoms. If even a single cigarette is smoked after the physical addiction is over, it is very likely that the smoking habit will return.

Perhaps the best cure currently available is the nicotine patch. The idea is basically to feed the addiction for nicotine while the urge to feel a cigarette in one's hands is treated. Once the nicotine patches are removed, the urge to smoke is less than quitting cigarettes cold turkey. See your doctor!

## Prevention

One of the many famous sayings attributed to Benjamin Franklin is, "An ounce of prevention is worth a pound of cure." (Of course, a chemist would read this as, "28.35 grams of prevention is worth 0.4536 kilograms of cure.") While this statement is insightful, the actual value of prevention depends on how the problem is avoided.

An important concept in modern medicine is preventive care. The greatest success of this method is the smallpox vaccine of 1796. Back then, smallpox was a leading cause of death. The vaccine caused a very mild form of the disease that helped a human body develop its defenses against the real disease. These defenses consisted of special chemicals called "antibodies" that selectively attacked the smallpox virus. Even today, this is the best way to handle a virus. The smallpox vaccine was so effective that the disease is almost unknown now.

Given the great success of vaccinations, you might think that everyone would want them. As it turns out, this is the one area of preventive care where the least money can produce the most benefits. To use Franklin's terminology, "One ounce of vaccination is worth two pounds of cure."

In other cases, preventive measures are not worth as much. For example, some blood tests are overused. It seems that many older Americans routinely test their cholesterol levels. While this can be important for those people who are at risk for heart attacks, the test is done too often on too many patients to be worth the cost. To use Franklin

again, "One ounce of cholesterol testing is worth a pound of cure for some patients, but for most patients, it is worth about an ounce of cure."

Likewise, too many people test their families for lead poisoning. Lead is a material that can cause mental and physical problems, and it is a serious matter. However, many people who are tested are not at risk.

Old paint and old plumbing are usually the cause of the high lead levels. In more innocent days, builders did not know any better than to use lead-containing materials. When little children eat the paint or the whole family drinks the lead-contaminated water, lead levels in the blood can reach toxic levels. However, because of all the publicity this problem has received, too many people are wasting money on blood screening. If you are at risk, then the test is worth it. You might want to ask a doctor if you are. Otherwise, you could be wasting precious ounces of prevention.

Another possibly costly form of prevention is radon detection. Radon is a radioactive gas commonly emitted from granite rock and nuclear reactors. While tightly sealed homes usually have lower energy bills, radon gas from rocky soils can build up in homes with little ventilation. Levels of radon gas in some homes are 40 times higher than levels allowed at nuclear power plants!

The key to wisely using your ounces of prevention is to make sure that you are at risk. If the soil around your home has a lot of granite in it and your home is tightly sealed up, it may be worthwhile to spend the $100 or so needed to test for radon. Also, if you plan to spend hundreds of dollars to seal up your home, it may pay to test for radon after finishing part of the project. This could help you avoid removing some of the sealing material to let the radon out.

In summary, while prevention is important, preventive measures can be wasted if not carefully chosen.

## Treatment for Heart Attacks

Heart problems are the major cause of death in the United States. This is actually a good thing since two major alternatives are famine and war. In the United States, diseases of old age such as cancer and heart attacks are the leading causes of death. Until there is some way to slow the aging process (or start a major war), these diseases will limit how long people can live.

It is ironic that taking steps to prevent heart attacks will increase the chance of dying from cancer! Of course, prevention or treatment of heart attacks will help many people live longer.

A large number of chemicals are used to treat heart problems. To treat heart failure, some drugs will strengthen heart muscles. Different drugs can control irregular heart beats. Blood vessels can be contracted by yet other drugs. Some drugs will expand (dilate) blood vessels. Glyceryl trinitrate (also known as nitroglycerin) is one drug that dilates blood vessels. It is also used as an explosive. Think twice before mugging senior citizens because they might throw their medicine at you!

High blood pressure (hypertension) can cause heart problems. Drug treatments for hypertension are of four types: diuretics that increase the flow of urine, drugs that affect the nervous system, drugs that enlarge (dilate) blood vessels, and calcium channel blockers.

Diuretics treat high blood pressure by reducing the volume of fluids in blood vessels and removing excess sodium. With less liquid to pump through the blood vessels, the heart does not have to work as hard. The sodium level is important because lots of salt in the blood can drive fluids out of the body's cells.

Cell membranes will let water pass through it but keep most other chemicals out. One characteristic of such a membrane (called a semipermeable membrane) is that the water will tend to flow to whichever side of the membrane has the most material in solution. Thus, if blood is rich in salts, then the cells it comes in contact with will lose water until the cells have the same concentration of dissolved materials as the blood. If blood has few salts, the water will flow into the cells.

(This last property can sometimes be used to kill germs. If you place some germs under a microscope and add a drop of distilled water to the slide, you will sometimes see a germ swell and finally pop as the water rushes into the cell. It is kind of entertaining in the same way that pulling the wings off flies is entertaining.)

Calcium channel blockers also involve cell membranes. Since cells normally block just about everything but water, the cells need ways for vital materials to pass through. Special channels through the cell membrane collect calcium ions from the body's fluid as needed by the cell. Calcium helps muscles contract.

Calcium channel blocking drugs block some of the calcium needed for heart contractions. The lack of calcium causes the heart to beat less

strongly and more regularly. These drugs can help treat diseases where the heart beats irregularly or too strongly.

## Antibiotics

Sir Alexander Fleming found the first antibiotic in 1928. However, it was years before any penicillin could be used by the public. He was simply not greedy enough to make a fortune off his discovery.

William Perkin, the inventor of synthetic dyes, and Leo Baekeland, the inventor of an early plastic called Bakelite, are examples of the right way to use a discovery. Both Perkin and Baekeland used their findings to make products that people wanted.

Fleming had some silly notions about wanting to reduce human misery. While that sentiment is better than wanting to rob banks, it hardly inspires other talented workers to work for you. Money does a better job of motivating workers. When Fleming had troubles purifying and testing the drug, he had to shelve the miracle drug for years. As a result, Fleming lost out on his chance to become rich, and millions of people died who could have been saved by penicillin.

Moral of the story: If you discover something of great value, do yourself and everybody else a favor by earning a fortune from it.

Antibiotics are materials made by living cells that kill or slow the growth of bacteria. These drugs have saved millions of lives that would otherwise have been lost to diseases such as pneumonia.

Fleming found that some molds could stop the growth of bacteria and isolated a chemical he named penicillin that killed his cultures of bacteria. Even today, most antibiotics come from molds, bacteria, and yeasts. Large vats of these living things are grown and then harvested to isolate the lifesaving drugs.

These drugs are sometimes chemically altered to produce new drugs. A variety of antibiotics is needed because prolonged use of a single antibiotic can cause two types of problems. First, the germs can become resistant to the drug. A resistant strain of bacteria will happily grow around the antibiotic that it has grown used to. The other problem is that the patient can become allergic to an antibiotic. In either case, another drug would have to cure the patient.

## Allergies

An allergen triggers an allergic response. For example, many people are allergic to pollen. The pollen enters the nose of the person and releases chemicals called "allergens." These chemicals are attacked by antibodies of the immune system. Reactions between allergens and antibodies release histamine that causes the sneezing, runny nose, and watery eyes.

Antihistamines reduce the symptoms of an allergy. They can make life much more pleasant for an allergy sufferer. In some cases, allergic reactions can even cause death. Death from bee stings is usually due to an allergic reaction to the bee's venom.

Finding the cause of the allergy can be simple or hard. If a cat or a flower causes a bout of sneezing or rashes, it is almost a no-brainer. However, an allergic reaction to food may be from anything eaten over the past three days. It can be difficult to tell which food is causing the problems.

One way to find the source of the allergens is to apply a little of the material to the skin and see if a rash develops. This method has a good record of success. Many people are allergic to the same things, and so the doctor is likely to find the cause quickly. Once the cause is found, treatments can begin. If nothing else, a good way to treat an allergy is to avoid the allergen. Antihistamines are great at reducing annoying symptoms, but do not cure the allergy.

Another problem with antihistamines is that they tend to cause drowsiness. This can be a benefit when trying to fall asleep at night, but during the day or working the night shift at a nuclear power plant, it can be a problem. Some regular users of antihistamines become resistant to the drowsiness side effect.

Avoid alcohol and hypnotics when taking antihistamines. The drowsiness from the antihistamines can be deepened by taking the other drug.

Note that antihistamines can also reduce the symptoms of a cold or flu.

## Skin Treatments

People tend to forget that the largest organ of the human body is skin. This shallow coating over the whole body serves many functions. It

protects the body against injuries by cushioning blows with a thin layer of fat. It senses temperature and touch. It regulates body temperature by sweat and changing the size of blood vessels near its surface. Sweat also cleans the body of waste chemicals and regulates the concentration of salt in the body.

Skin does a fair amount of chemistry. To remove waste products, it concentrates the waste into little drops of sweat and pushes this liquid to the surface. The process takes a lot of energy because waste products, like all chemicals, tend to stay dilute until work is applied to concentrate them.

Two different types of pores are used in the skin. One type specializes in oil while the other specializes in water. Since oil and water do not dissolve in each other, it only makes sense for the body to treat them differently.

Skin also makes vitamin D when exposed to sunlight. Like plants, humans can die when not exposed to sunlight — assuming that those people in the dark do not get vitamin D from their food.

Many types of chemicals are placed on the skin to clean, remove blemishes, soothe, and heal. Soothing substances can be applied to irritated skin or mucous membranes. These soothing materials protect the areas where they are applied. Also, they reduce the urge to scratch those areas.

Emollients are fatty or oily substances that, when applied to skin or mucous membranes, protect against air and air-borne irritants. A thin layer of oil keeps the irritants out. At the same time, the skin under the oily layer is made softer as the oil penetrates into the skin and makes the skin more pliable. Some common emollients include petrolatum, rose water ointment (found in cold cream), and hydrous wool fat. Hydrous wool fat is also called "lanolin" and is a mixture of fatty esters.

Astringents reduce the loss of blood from minor cuts and slow other secretions from the skin. These chemicals usually go directly on the areas where the liquid is coming from. Astringents are the chemicals that make antiperspirants work. Some common astringents are salts of metals such as aluminum and zinc, tannins such as tannic acid, alcohols such as ethyl alcohol (grain alcohol), and phenols.

Astringents work by precipitating proteins out of blood or sweat. Proteins dissolved in water or oil react with the medicine to fall out of solution as a solid. This process of falling out of solution is called "precipitation" — just like rain falling down. The visible results are drier

skin. Most astringents only affect liquids on the surface and do not penetrate the skin.

## Acne

Acne is a problem for many teenagers and some adults. Fortunately, there are several treatments for it.

The best cure for acne would be to avoid it altogether. One way to try to avoid it is using only cosmetics that are "hypoallergenic." ("Hypo" means "under" or "less." "Allergenic" means "causes allergies.") This type of cosmetic is less likely than most to cause skin irritation. Also, water-based makeup does not cause an oily buildup that can clog pores and cause acne. Clean hair worn off the face with a minimum of gels, creams, and sprays also slows the clogging of pores.

The link between food and acne is unclear. The iodine in seafood causes problems for some people while other people break out in acne after eating chocolate. Also, some people get acne after eating acid fruits such as oranges.

To clean the clogged pores that cause pimples, acne sufferers should wash twice daily with a mild, non-irritating soap. Products using astringents to dry the skin (such as Stri-Dex Pads or Clearasil) can speed the healing of blemishes.

As the ads say, benzoyl peroxide is the strongest acne medicine you can buy without a doctor's prescription. It is so strong that some users have had to stop using it because of skin irritation. Benzoyl peroxide oxidizes the outer layer of the skin which then peels off. Since most pimples are in the outer layer of the skin, the skin soon looks better. Within six to eight weeks, the results should be clear.

Antibiotics are sometimes applied to the skin to fight bacteria that can cause acne. These solutions go directly on the skin.

Retinoic acid can reduce acne, repair sun-damaged skin, decrease the number of wrinkles, and even treat some types of skin cancer. However, the early users of this wonder drug found that it had a nasty side effect. Prolonged use of the creams would result in skin problems including flaking of skin and burning sensations. For this reason, many of the early patients have stopped using the product.

Some chemists at Hoffmann-La Roche have found that adding a second chemical reduces the unwanted side effects of retinoic acid without harming its useful effects. Those people who have had trouble with this

drug before may have better luck with the new treatment. In case you are curious, the new additive is called "alpha-tocopherol" or "vitamin E" for short.

## Cancer Scares

As pointed out earlier, the risk of food additives causing cancer is smaller than the risk of the food itself causing cancer. But if you watch a lot of TV, you might think that artificial chemicals cause all cancer. The major media are worth pretty much what you pay for them — at least concerning science.

As this book goes to press, there is no way of knowing what the next scare will be. However, it is worth reflecting on a scare that is no longer covered by the newspapers. A man named Paul Brodeur invented the idea that electromagnetic fields from power lines and appliances cause cancer and other diseases. The press was quick to jump on the story. However, the evidence for this claim was very weak. When the topic grew dull and most people decided that the story was probably exaggerated, the papers stopped writing about it.

Almost every day, news people cover stories like that. From Alar to dioxin to cellular telephones, many inventions get this sort of hit-and-run treatment. It helps to be skeptical of scare stories.

# Chapter 6

# Cars and Chemicals

Cars have some of the most useful and exciting chemistry known to humans. Imagine thousands of little explosions causing tremendous heat and whirling hundreds of parts faster than the eye can see. Fluids rarely seen in nature protect and lubricate these parts. Large vehicles often go at speeds that birds would find hard to maintain.

If this sounds more interesting than a chemistry class, you were born too late. At some point in the distant past (the 1940s), you might have heard a lecture or two about the chemistry of engines in a science class. Educators since the 1960s have been draining chemistry classes of much of their usefulness. This chapter will introduce a whole new generation to this chemistry.

However, the science of automobiles is quite deep. It would be impossible for a beginning chemistry book like this to cover the subject in all its gory details. Still, you will learn more about this topic than if you sat through ten chemistry courses. It is strange that such a useful topic was dropped.

## Where a Car's Energy Goes

The energy from burning gasoline becomes mechanical, electrical, and heat energy. Ideally, the fuel would be used for mechanical work such as pushing the car up a hill, or electrical work such as playing the radio. Actually, less than 50% of the energy can be used for those purposes. Much of the energy is wasted as heat.

## Energy losses

Only about 13% of the energy in the gasoline pushes a car forward. Much of the energy is lost in the engine. Many engines are only about 37% efficient. Most of the energy in gasoline is wasted as heat or unburned exhaust fumes.

The loss in the engine is largely due to the temperature range. In general, the higher the operating temperature; the greater the efficiency of the engine. Most cars do not have steam engines because those engines work at lower temperatures and are less efficient. Because diesel engines operate at higher temperatures, diesel engines tend to be more efficient.

Besides the temperature effect, some energy is lost in the engine because of friction and pushing viscous (thick and gooey) oil. It takes work to move parts that are scraping against metal or meeting resistance from a viscous oil. This work does not push the car forward but still consumes fuel.

Much of the energy that leaves the engine does propel the car. Only about 2% of the energy from gasoline goes to the accessories such as air-conditioning, rear-window defrost, and power windows.

Around 4% of the energy from fuel is needed to overcome the tires' resistance to rolling. The harder the tires; the smaller the rolling losses. Hard tires also last longer. However, hard tires do not grip the road as well as softer tires. The poor traction can be dangerous in sharp turns or sudden stops. Any tire represents a trade-off between high gas mileage and long life versus good traction.

Almost 3% of the energy is lost to aerodynamic drag. Flat surfaces and sharp edges on the car's body are likely to slow the car down, as will a solid back gate on a pickup truck. That is why all cars are beginning to look alike with the same sleek styling, and trucks are more often using a net for the tailgate. However, fancy curves also make body work more difficult. On newer cars, it is simpler to replace a body panel than to bend it back into shape. (The use of plastics instead of steel also encourages replacement rather than body work. It is easier to work with steel than plastic.)

About 4% of the energy in gasoline is wasted by running the engine when the car is standing still. If this energy could be stored, gas mileage could improve about 30%. Some books advise turning off the engine if forced to stand still for more than a minute. A complete redesign of the engine could also help. However, this is not something that most do-it-

yourselfers would want to try on their family car! In an electric car, the energy loss from standing still would be small. A flywheel-equipped car could store the energy in the flywheel rather than just wasting it. Both of these approaches have their own problems.

About 6% of the energy goes to heat up the brakes to slow the car down. In cars with a flywheel, some of this energy can be recovered by making the flywheel spin faster. However, the greater complexity of cars with a flywheel makes repairs more costly.

About 6% of the energy goes to friction losses in the drive train. Good lubrication is needed to keep this figure low.

### The first law of thermodynamics

The first law of thermodynamics lets engineers add up the different uses of energy like an accountant tracks money used by a firm. This law can be very useful as it makes it possible to find where all the energy goes.

For one engine, it was found that 32% of the fuel's energy was converted into mechanical energy. The cooling system (the radiator) took 28% of the energy in the form of heat. The remaining 40% was split between unburned fuel and radiated heat.

This sort of accounting can be handy for those who design or fine-tune cars. In the engine above, the 32% conversion of fuel into mechanical energy might be pushed closer to 37% by reducing the losses from unburned fuel.

## The Internal-Combustion Engine

Gasoline (or other fuel) is converted into water, carbon dioxide, heat, and pollution inside an internal-combustion engine. This type of engine powers almost all cars and trucks.

This engine gets its name from the type of reaction it uses. The reaction of a fuel such as gasoline with oxygen to form water and carbon dioxide is called "combustion." It is perhaps the most important chemical reaction because combustion is the basis of fires and even powers living things as well. (Mother Nature is more subtle and can do the reaction in water.)

To derive energy from combustion, a mixture of fuel and air is squirted into a chamber (also called a "cylinder"). When the mixture is ignited into flame, this sudden increase in pressure pushes a movable wall

called a piston. The piston moves — expanding the volume of the chamber and relieving some of the pressure. The work it takes to push the piston down can be converted into either mechanical energy to turn the wheels, or the alternator can change it back into chemical energy for storage inside the battery.

### The fuel mixture

The carburetor provides the fuel mixture and sets the ratio of fuel to air. Too little fuel and the explosion in the chamber is weak with little power. Too much fuel and there is too little oxygen to burn all the fuel. This can waste gas.

When you put your foot on the gas pedal, you are adjusting how much gasoline mixture is added to the cylinders. More fuel mixture results in more energy. The process of adjusting the quantity of fuel mixture has a rather violent name: “throttling.”

A problem called “flooding” is sometimes caused by pumping the gas pedal when starting a car. If the engine will not start and the electronics seem to work, it is possible that the chambers have too much fuel in them to start (they are “flooded”). There might be too little oxygen in the cylinders for the spark plugs to ignite the fuel.

Check under the hood for a few minutes pretending to know what all those engine parts do. You should be able to smell gasoline. By waiting a few minutes, some of the gasoline in the cylinders will evaporate. Then push the gas pedal to the floorboard to introduce a lot of fuel mixture to the cylinders. (The fuel mixture is mostly air.) Cranking the engine for ten seconds should burn the extra gasoline. If this does not work, you may have another problem.

### The engine cycle

Car engines work in a cycle (a repeating pattern of actions). The piston goes down, expanding the volume of the cylinder, and a mixture of fuel and air enters the chamber through an inlet valve. With the valves closed, the mixture is compressed (squeezed). At the top of the compression stroke, a spark ignites the fuel mixture and the increased pressure from the burning fuel pushes the piston down. As the piston goes down, it can do useful work.

Later, the piston comes up again and exhaust gases leave through the exhaust valve. Then the second cycle can begin with the piston

dropping to expand the volume of the cylinder again, and another sample of fuel mixture enters the chamber.

## Power

It is easy to get confused about the term "power." Some people use the word when they mean "control." For example, Congress has "power" over the government. When talking about cars, "power" means the ability to haul a heavy load at good acceleration or do a lot of work quickly. This is not to be mixed up with Congress' ability to spend a lot of money quickly. As a rule, cars work and Congress spends. That is the difference between the two meanings of power.

Power is the rate at which energy is produced and used up. "Horsepower" is a unit of power equal to 0.18 food calories per second. This strange number is a symptom of a big problem in science. Every group of scientists has units they like to give their results in. However, the thousands of units make it time-consuming to compare the answers. This chapter uses food calories for energy to help calorie counters understand how their car works.

Horsepower originally came from the power a horse could produce. If a rider carried too much weight, the horse would suffer. Today, if a driver overloads his or her car, the handling and fuel economy go down. Every extra 100 pounds can lower fuel performance by up to one mile per gallon. It takes more power to accelerate a heavy load. It pays to travel light.

For every temperature, there is a maximum amount of power possible for an engine. When the cylinder is full to the top with the ideal blend of fuel and air, the resulting explosion is as strong as it can be. Colder temperatures increase the density of the fuel, and can result in a more powerful explosion.

## Engine displacement

Engine displacement is often given in liters (for example, a three-liter engine). A liter is a unit of volume about the same size as a quart. You can picture the engine being dunked into a tub full of water. The engine will displace an equal volume of water, and that water will splash over the sides of the tub. When the water is collected, the volume of the displaced water determines the displacement of the engine.

Note: When Archimedes discovered displacement by stepping into a tub full of water, he was so excited that he ran around naked while yelling

"Eureka!" Hopefully, only a few readers will do that after reading the above paragraph.

## Fuel

In Europe during World War II, cars burned solid fuels such as coke, charcoal, or wood shavings. These cars needed a special piece of equipment, called a "producer," that converted the solid fuel into a gas. This gas, called "producer gas," was a mixture of hydrogen, nitrogen, and carbon monoxide. Producer gas was the fuel that powered the engine.

Few of these cars remained on the road as soon as liquid fuels became available again. Liquid or gaseous fuels flow easily to where they are needed and do not need a producer.

By the way, "synthesis gas" is made by treating coal with steam at high temperatures. It is basically producer gas without any nitrogen gas. Synthesis gas can then be converted into methane and burned like natural gas.

Early attempts at using gaseous fuels in cars also ran into problems. At low pressures inside the gas containers, the gas ran out quickly and only short trips were possible before refueling. At high pressures, longer trips were possible, but at the cost of carrying a heavy container of the gas. The gas tank was also costly to refill.

Early gases were petroleum based. However, the same problems are faced by the makers of hydrogen-powered cars today.

### Petroleum

Most cars are powered by fuel distilled from crude oil. Crude oil is the remains of plants and animals buried underground for millions of years. Over time, this material turned into the smelly, ugly, black gunk known as crude oil. For many years, this oil was disliked by landowners. Now, it is thought of as a valuable resource that can fill the need for energy and chemicals.

Because it takes so long to form a new batch of crude oil, most economists and chemists would call it a nonrenewable resource. Despite many predictions that humans would totally deplete the world's supply of oil, more oil is found every time the price of oil goes up. In any case, saving money by using gasoline and oil more efficiently can help a family's income go further. Whether it helps to save the earth does not matter much to most families.

### Miles per gallon

"Miles per gallon" is a quantity that helps determine how much a car costs to maintain. It can be found by either reading the sticker on a new car or by keeping a log of miles driven and gallons of gasoline put into the car. Just divide the miles driven by the number of gallons consumed. A large number for miles per gallon (MPG) means that the fuel costs per mile driven are small. The MPG is a handy number to have, although it only reflects part of the cost of driving a car.

Hard driving can lower your miles per gallon. The great scientist named Isaac Newton showed that it is not velocity (how fast your car goes), but rather, acceleration (how fast its speed is increasing) that requires energy and eats up gasoline. Even to slow down from a high speed requires energy from your brakes. That is why stop-and-go city driving always has a lower MPG than highway driving. If you stop and go on the highway, I do not want to drive behind you.

Because of a sharp increase in gasoline prices during the 1970s, the average miles per gallon has greatly improved since 1974. In that year, the average car got 14.2 MPG while in 1988 — just 14 years later — that had doubled to 28.6 MPG. At that rate, cars will get 3.5 miles per ounce in the year 2058!

### Energy values of milk and gasoline

Even though milk is a food rather rich in fat and food energy, it has far less energy than gasoline. A gallon of 2% milk has 1,920 food calories while a gallon of gasoline has 30,000 food calories. While your car consumes chemical energy just as you do, you and your car need different sources of energy. Your car will not work if you put milk in the gas tank. Also, do not try to drink gasoline because your body cannot digest it.

## Engine Knock

Engine knock occurs when a second explosion occurs inside the cylinder after the spark plug ignites the fuel mixture. This second explosion sends out pressure waves that create the sound of knocking. The extreme heat from knocking can damage the pistons. High-octane fuels reduce knocking in gasoline engines.

## Octane numbers

Situations that require a lot of power from the engine require a high-octane gasoline. This type of fuel would be useful when pulling a heavy load, climbing a steep hill, or drag racing. The octane number comes from mixing isooctane and heptane (two types of gasoline) and testing how easily the blend "knocks" in an engine. Pure heptane knocks quite often and has been given an octane number of 0. Isooctane rarely knocks and has been given an octane number of 100. Actually, fuels with octane numbers above 100 are possible, but most engines work OK with lower octane fuel.

Three out of four cars can run on 87 octane. Check your owner's manual to see what number your car needs. If the car starts knocking and you are using the type of gasoline recommended in the owner's manual, the car may need engine work.

If you cannot find the owner's manual, a way to determine the proper octane number is to accelerate rapidly from a complete stop. First, have a mechanic check the engine to make sure that the engine, carburetor, spark plugs, and so on are all working right. Then, fill the gas tank with gasoline of the octane number desired. After driving 10 to 15 miles to warm up the engine, come to a complete stop (maybe at a traffic light) and then step on the gas hard. If the engine makes a pinging noise, use a higher octane gasoline on the next fill-up. (As Isaac Newton would say, the car need not be going very fast for the pinging noise to start. Also, the car does not have to be tested very often, even by those people without an owner's manual.)

Diesel engines use a type of fuel that is less volatile than gasoline. That is, gasoline goes from a liquid to a gas (evaporates) more easily than diesel fuel. Since diesel fuel is different from gasoline, diesel fuel does not use the octane rating system. Diesel fuels use the cetane system instead.

The cetane rating system uses cetane and 1-methylnaphthalene. Cetane causes very few knocks in diesel engines and is given a rating of 100 as a diesel fuel. 1-methylnaphthalene is very prone to knocking in diesel engines and is rated 0 as a diesel fuel. Other diesel fuels are compared to mixtures of cetane and 1-methylnaphthalene to find each diesel fuel's rating. The rating of a diesel fuel is called its cetane number.

### Raising fuel ratings

A refinery first splits crude oil into fractions based on boiling point. Very high boiling fractions become asphalt or lubricating oil while fractions that quickly turn into vapors become butanes for stoves or lighters. Gasoline is less volatile than butanes and comes off as a fraction. Diesel and jet fuel are less volatile than gasoline and come off as other fractions.

However, gasoline and diesel fuel straight off the distillation tower are poor fuels in engines. The gasoline has a low octane number and the diesel fuel has a low cetane number. The refinery does a series of chemical reactions on the straight-run fuels to increase their value. "Cracking" changes high-boiling fractions into gasoline. Alkylation, isomerisation, and reformation increase the octane rating of gasoline. These reactions are best done on a large scale. Do not try this at home!

## Gasoline Additives

Gasoline at the gas pump has been blended to improve its fuel properties. Additives such as benzene or alcohol may be added to raise the octane number. Some volatile fuel may be added to make starting in cold weather possible. Also, chemicals that remove water from the fuel system are sometimes added. The result is a complex mixture.

### Methanol

Methanol is sometimes added to gasoline. Methanol (also known as wood alcohol) is a low-boiling, flammable liquid. It is sometimes added to make it easier to start the engine on a cold day. It also reduces the cost of gasoline when methanol prices are cheap. Like other additives, it can be toxic and may be absorbed through skin. However, most self-serve gas pumpers are not exposed to enough of it for that to be a problem.

Methanol does have some problems. It dissolves in water, and so water is more likely to be found in gasoline containing methanol. Methanol also carries with it a supply of oxygen. While gasoline is only made of carbon and hydrogen, methanol has oxygen as well. The extra oxygen can change the optimum ratio of fuel-to-air for combustion. The extra oxygen can generate extra heat inside the cylinders and increase engine wear.

Some owners' warranties will not cover certain engine repairs if the owner uses methanol-blended gasoline. Check with the owner's manual first. If the manual advises against using this type of gasoline, ask the gas

station owner where you usually buy gas if it contains methanol. This is sometimes not marked on the pump.

### Alcohol

Ethyl alcohol (grain alcohol) is sometimes cheap enough to use as an additive. In gasoline engines it burns much like the regular fuel. Alcohol, however, contains some of its own oxygen. Therefore, the carburetor or fuel injector should be adjusted to change the fuel-to-air ratio when switching between gasoline and alcohol.

Another serious problem with alcohol is its tendency to absorb water out of the air. Chemists call gasoline "hydrophobic" ("hydro" means "water" and "phobic" means "afraid"). Because gasoline tries to avoid water, it rarely has much water in it. However, as many drunks can testify, alcohol loves water. Alcohol will form solutions with any ratio of alcohol to water. For example, a martini can be made as strong as the drinker wants. Scientists call water and alcohol "miscible" because they form a complete range of solutions.

While it is nice to see young chemicals in love, this courtship can result in water at the bottom of a gas tank that uses alcohol. When the alcohol is exposed to moist air, it soaks up some of the water in the air. Over time, the quantity of water in the gas tank can build up to the point where it causes problems. The problems include corrosion inside the tank and a difficulty in controlling the ratio of fuel-to-air. Also, switching back to gasoline may result in the fuel line freezing in cold weather if some water escapes from the gas tank.

### Lead

Because lead is a poison if consumed, its use in gasoline has been outlawed. Before this action, tetraethyl lead was added to help reduce engine knock. This form of lead dissolved in gasoline and slowed the chemical reactions that produce knocking.

### Detergents

Detergents are a useful additive for cars with fuel injection. Dirt can build up in the injectors and clog the pores that squirt gasoline near the cylinders. Detergents help dissolve the dirt and keep the injectors working well.

Note that the detergents in gasoline are different from those used to wash dishes in a kitchen. When washing dishes, detergents are dissolved in

water and remove greases. As a gasoline additive, detergents are dissolved in gasoline (a greasy material) and remove dirt that is usually soluble in water. As you may have guessed, it would be a big mistake to put dishwasher detergent into your gas tank!

Both types of detergents dissolve materials that normally would not dissolve in each other. As a rule, "like dissolves like." If something is like salt, it will often dissolve in water. If something is like grease, it will usually dissolve in gasoline. Detergents can allow water to dissolve grease or gasoline to dissolve salty deposits.

Those cars with fuel-injection engines could use a gasoline with detergents added. Cars that have a carburetor instead of fuel injectors do not need detergents as much. Fuel injectors clog more easily than carburetors do. Of course, if you start to see soap bubbles come out of the engine while you are driving, it is time to cut back on the detergents.

## Filling the Tank

It is best to wait until the gas tank is around one-quarter full before filling up. It takes time to fill up a gas tank and filling up less often saves time. However, waiting too long is risky for obvious reasons.

This rule of thumb changes in very cold weather. A nearly full gas tank leaves less surface area inside the tank for moisture to condense on. Keeping the tank nearly full can reduce the chance of water freezing in the fuel line. Drying additives help, too.

Buying gasoline when it is cool outside gives a little more gas for your money. This is because gasoline is sold by volume (gallons) while a more accurate measure would be mass (pounds). The relationship between mass and volume is called density. The mass of one gallon of gasoline is about 6 pounds. (This compares to water that weighs about 8 pounds per gallon.) Density, the mass of a volume of the material, changes with temperature.

Because the density of a liquid is usually higher when it is cool, buying cold gasoline gives you slightly more for your money than buying warm gasoline. Likewise, filling the tank to the top when it is cool can lead to the gasoline expanding as it warms up and maybe overflowing. Be sure not to overfill your gas tank.

## Fuel Injection

Carburetors have some drawbacks. For example, it is hard for many of them to distribute the fuel mixture evenly to all the cylinders. Also, in cold weather, fuel can be deposited on the walls leading to the cylinders. This fuel buildup can lead to problems.

In comparison, there are many benefits from fuel injection. Even on a cold day, starting the motor is easier (assuming your battery is OK). Fuel goes to where it is needed with fewer losses on cold walls of the engine. The fuel can be distributed as needed by the driving and weather situations to get the most from each cylinder.

However, this peak performance comes at a high cost: more ways for the engine to fail, and the higher level of skill needed to fix it if it breaks. Still, with emission controls making carburetors more complex, fuel injection is probably the best buy unless you want a really cheap car and do not plan to drive it in California. (That state has stricter air pollution laws than most states.)

In case you are wondering, the fuel is not injected directly into the cylinder. The heat and pressure in there are just too great. Instead, the fuel is squirted out just below each intake valve or someplace a little farther away. The farther away it is injected; the more distribution problems can arise.

## What Air Filters Do

The air that a car engine uses in a short time could fill a room. This means that a lot of dirt and dust would clog the engine if that air is not properly cleaned before combustion. The air filter cleans out most of the dust from the incoming air to protect the engine. The air filter should be serviced when the owner's manual calls for it. When the air is very dusty, the filter may have to be replaced more often.

## Oil

Oil is a fluid that keeps the moving parts of a car's engine from grinding against each other. This grinding would cause damage to the moving parts, and the heat from grinding could melt other parts. (The heat from grinding is due to friction. Hard rubbing will change mechanical energy into heat energy) Routine checking of the oil level, regular changes of oil, and replacing the oil filter are critical for keeping the engine

working. If that maintenance is done regularly, many engines will last as long as the cars do.

Oil comes in a variety of viscosities. Viscosity is said to be "high" when the fluid is as thick as molasses. A high viscosity fluid requires more work to move through than a low viscosity fluid. A high viscosity fluid such as honey would be tougher to swim in than water. If you do not believe me, just try it!

Higher viscosity protects the engine better but increases the energy required to move engine parts. Thus, a high viscosity oil may cut down on engine repairs but could reduce the car's miles per gallon.

By the way, please do not put honey in your car's crank case! Oils are carefully made to survive high temperatures in the engine without changing viscosity. Honey would quickly burn up at those temperatures and the solid residue would be of no use in protecting the engine parts. The parts would rub together with the resulting heat ruining the engine.

If you still have the owner's manual for your car, you should follow its suggestions for the grade of oil to be used. A common oil viscosity is 10W40. This is shorthand for "10 winter" with the 40 standing for summer. To translate this further, the viscosity is similar to a runny 10 weight in the winter and is similar to a thicker 40 weight in the summer. By having thinner oil in the winter, the engine can start more easily when the weather is cold. If you have played with cold honey for a while, you may have found that it becomes more viscous at lower temperatures. Multigrade motor oil keeps most of its viscosity at higher temperatures and does not become as viscous as honey does at cold temperatures.

The viscosity ratings of motor oils range from 5 (runny liquid) to 80 (a honey-like liquid). These viscosity ratings are called "weights." So, an oil with a rating of 40 would be called 40 weight. It is not clear why the term "weight" is used to describe viscosity. It makes about as much sense as describing the loudness of a sound as "volume." Still, when talking to the experts, it helps to know the jargon.

You may notice the letters "SA," "SB," "SC," "SD," "SE," or "SF" on the oil can's label. These letters are the ratings of oil by the American Petroleum Institute (API). SA is the lowest rating for a motor oil. SF is the highest rating while the other ratings are in alphabetical order. Tests at API show that oils rated SD or SF reduce engine wear more than oils rated SA or SB. Therefore, switching to SF can extend the life of the engine — assuming that the car is not totaled in an accident first!

Besides lubricating engine parts to reduce friction and heat, oil also collects dirt and metal chips and runs them through the oil filter to keep the engine clean. Oils contain additives such as detergents to help the oil carry away dirt.

Synthetic oils can reduce friction and last longer than traditional oils. These oils may slightly improve gas mileage or engine life. However, it is still necessary to change the oil and oil filter every 3,500 miles or so, because the grime can build up unless the oil is changed. These synthetics can be compared to SF oil.

## The Cooling System

The cooling system consists of pipes surrounding the engine with a flowing liquid. This liquid — which is 50% water and 50% antifreeze — takes heat away from the engine. The heat then leaves the car through the radiator.

Without this system, heat in the engine compartment would rapidly accumulate. At the higher temperature, the parts of the engine would expand (increase in size). Since many parts must fit together, such as the pistons and cylinders, expanding these moving parts can lock them tightly together. When the parts can no longer move, they are called "frozen" by mechanics.

### Filling the cooling system

Be sure that the liquid in your radiator is a mixture of water and antifreeze. Antifreeze is mostly ethylene glycol.

The water quickly transfers the heat from the engine into the coolant and warms up slightly to store the energy. The antifreeze helps keep the water from boiling over from the heat or freezing in cold weather. Using straight antifreeze will often overheat the engine because, by itself, antifreeze does a poor job of taking heat from the engine and storing it.

Most bottles of antifreeze recommend using between 50% and 70% antifreeze with the rest being water. To reduce the buildup of lime deposits, it is wise to use distilled water instead of tap water to dilute the antifreeze. Because distilled water has been evaporated and then the water vapor (also called steam) condensed, most of the impurities found in tap water have been removed.

In winter or summer, using extra antifreeze (60% to 70% instead of 50%) will simultaneously raise the boiling point and lower the freezing

point of the coolant mixture. It often happens that dissolving things into water will lower the freezing point and raise the boiling point. The extra material makes it harder for crystals to form and harder for water at the surface to escape the liquid phase and turn into a gas. These are examples of what are called "colligative properties." These properties depend on the amount of stuff in solution rather than what the stuff is.

Adding water instead of a 50-50 mixture of water and antifreeze is not good. This practice could result in frozen coolant or overheating of the engine. By always adding the mixture, these problems can be avoided. If the coolant is less than 50% antifreeze, it would probably be wise to flush the radiator and put in new coolant. In any case, replacing the coolant once a year helps to avoid a buildup of dirt in the cooling system.

## Batteries

Some very interesting chemistry occurs in a car battery. Reactions take place every time electricity flows from one terminal to the other. When a battery is giving off energy, chemicals inside the battery are going from high-energy states to more stable forms. When the alternator puts energy into the battery, the chemicals inside the battery return to their high-energy states.

The electrical energy from the battery is used in a variety of ways. It is changed into light in light bulbs. The radio converts it into sound. The air conditioner uses it to pump heat out of the car. Door locks use electricity to lower the door-lock knobs (an example of mechanical work). The defroster changes electricity into heat.

Some older car batteries need to be filled with water regularly. If the water level goes down, the concentration of the battery fluid increases. That is, more solute such as sulfuric acid will be dissolved in each cubic inch of solution. When the battery solution becomes too concentrated, the performance of the battery can suffer.

In cold weather, distilled water freshly added to the battery might freeze. The battery fluid does not freeze because the chemicals dissolved in it lower the battery fluid's freezing point (another example of a colligative property). However, freshly added distilled water may not mix well with battery fluid for several hours. If it is below 32 degrees Fahrenheit, the distilled water might freeze and cause damage to the battery.

When adding water on a cold day, it is necessary to keep the battery above freezing temperature. One way to do that is driving the car around for an hour or two after adding the water.

Most new batteries do not require the addition of water. This not only saves time, but is also safer because many batteries use a solution of sulfuric acid as the battery fluid. Sulfuric acid is a chemical that corrodes metal and burns holes through most organic materials (such as skin or clothing). It is widely used but can be dangerous. If you spill some battery fluid on yourself, be sure to wash it off right away with lots of water!

The only upkeep that a modern battery needs is regularly checking the terminals to make sure they do not become heavily corroded. Corrosion ("rusting" if the posts are made of iron) is an electrochemical process. The voltage at the battery posts can cause the posts to react with moist air and corrode faster than the rest of the car. A corroded or dirty terminal can stop the flow of electricity out of the battery.

Be careful if you chose to clean the battery rather than replace it. Touching the terminals of a battery might result in a severe shock. (Though normally, no shock results because the do-it-yourselfer is not grounded. Avoid messing with a battery when standing barefoot in a puddle of water.) Also, do not smoke around car batteries or expose them to sparks. Car batteries can change water inside the battery back into oxygen and hydrogen. While oxygen is not too bad, hydrogen can easily catch on fire.

Besides letting the battery run down (perhaps due to a faulty alternator), there are two major causes for car batteries failing. First, vibrations can cause damage. Firmly clamping the battery in place will stop this problem.

The other cause of battery failure is lead sulfate forming insoluble crystals. Lead sulfate normally dissolves in battery solution enough to change back to lead when the battery is recharged. However, if the lead sulfate forms a certain type of crystal, it may be slow to go back into solution. A loss of power is the result.

It is possible to test the battery fluid to find out how much energy remains. The battery makes energy when sulfuric acid combines with lead to give crystals of lead sulfate. As energy is removed from the battery, the amount of lead and the concentration of sulfuric acid goes down. It is hard to find out how much lead is left in the electrodes without taking the

battery apart. However, it is fairly simple to find out how much sulfuric acid is left.

Pure sulfuric acid is about 1.84 times as dense as water. While one pint of water weighs one pound, one pint of sulfuric acid weighs about one pound and thirteen ounces. When mixed with water, the resulting solution is more dense than water but less dense than sulfuric acid. The more dense the solution; the more sulfuric acid is in it.

A simple device called a "hydrometer" can measure the density of a liquid. It can be used to find the density of battery fluid and, indirectly, how much sulfuric acid is left in solution. When fully charged, the fluid has a density of about 1.28. With no charge, the fluid has a density of 1.15. The lost sulfuric acid goes into crystals of lead sulfate.

### An energy saving tip

Air conditioners (and to some extent, heaters) use lots of energy from gasoline — by way of the alternator and the battery. Using heat from the engine and wearing a coat helps in cold weather. On a hot day, rolling down the window costs less energy at low speeds. At highway speeds, the air conditioner is cheaper to use than an open window because it does not cause a drag on the car.

## Ignition

The ignition system is made of the distributor that sends electricity from the battery to the spark plugs, and spark plugs that ignite the fuel mixture. If your car starts slowly in wet weather, it is possible that the cap of the distributor is cracked and is letting moisture into the ignition system. This can short-circuit some of the wires and can also cost fuel. Replacing a cracked distributor cap can save more fuel than replacing a bad spark plug. Replacing a bad spark plug can also pay for itself.

## Electronic Control System

The electronic control system controls the fuel mixture. It adjusts for the temperature and the work load to keep pollution at a minimum. To do this, it monitors the fuel mixture, the exhaust, and temperatures in and around the car.

Modern cars with this system are more expensive and can be costly to repair. Fixing this system is not a do-it-yourself project. However, the

power and gas mileage are often better for these new cars than for older models.

## Emissions

Emission control devices recycle fuel that would otherwise go out the exhaust unburned. They also reduce the amount of gases that might pollute the air.

The Federal Clean Air Act provides for fines of up to $2,500 for anyone who tampers with these devices. While California enforces this law most strictly, drivers in other states are also subject to it. Sensors that can be mounted on highway overpasses are a good way to enforce the law. These sensors send out an infrared beam that detects carbon monoxide and hydrocarbons such as unburned fuel.

The condition of the engine and the exhaust system largely determines how much pollution the car spews out. Only a few cars account for most of the pollution. A recent study found that the dirtiest 10% of the cars accounted for about half of the pollution. Half of the cars caused only 5% of the pollution.

People who tamper with their emission system cause a lot of the air pollution. Do not tamper with your emission system because you may have to pay a large fine. It can also pay to have your engine checked from time to time to reduce pollution and find out if the fuel is burning completely.

Diesel engines often put out less hydrocarbons but more soot (tiny particles of carbon). Soot is formed by heat and pressure where there is little oxygen. These conditions are more common in diesel engines than gasoline engines. Soot does not cause smog in the way that hydrocarbons can. However, it is still a serious pollutant because the soot particles can be inhaled and cause lung cancer.

Diesel engines also produce more nitrogen oxides than gasoline engines. At the higher operating temperatures inside diesel engines, more of the nitrogen gas in the fuel mixture reacts with the oxygen to form nitrogen oxides. These gases can promote smog. Catalytic converters change nitrogen oxides into nitrogen and oxygen.

### PCV valve

Positive crankcase ventilation (PCV) is used to recycle unburned fuel vapors from the crankcase back to the engine. The crankcase holds the car's supply of oil. If the valve in the PCV becomes clogged, it can

reduce engine power, waste gas, and increase pollution. Because of the ease of fixing the PCV valve, it should be checked at every oil change.

## Supercharging

Many people want the most power from each piston stroke. Some want better fuel economy (accountants) while others want more power (race car drivers). It is the air (really the oxygen in the air) that usually limits the power from each explosion. For that reason, more air in the fuel mixture often gives more power from less fuel.

A second carburetor can increase the content of air in the fuel mixture. It should help improve the car's power if the engine is properly adjusted. To make use of the extra oxygen, the compression ratio should be increased. That is, the fuel mixture should be pushed upon harder by the piston before ignition. Note that it is far easier to buy a car like this than to modify your current car.

Supercharging does even better by pressurizing air. Air is drawn into a blower by a difference in pressure and compressed before carburation. Gases can be compressed so that the same mass occupies a smaller volume. Liquids, such as gasoline, cannot be compressed regardless of how much pressure is placed on them. Increasing the pressure on the fuel-air mixture increases the density of air in the fuel mixture without changing the mass of the fuel. As a result, more oxygen is present in the same volume of fuel-air mixture. The power from each stroke increases. Both gasoline and diesel engines can be supercharged.

## Auto Cleaners

Most auto cleaners use the same sort of chemistry as other cleaning solvents, soaps, and detergents. The key to cleaning something is usually to get the crud on it to dissolve in a solvent and wash away. Different solvents with various detergents are used — depending on what the crud is and what should be left behind. The detergent dissolves the dirt, and the solvent washes the dirt away.

Like fine furniture, many people want their cars to look nice between washings (dustings?). While varnish is used to protect wood, waxes and polymer coatings are put on the outsides and insides of cars to protect the plastic and paint. They provide a thin layer on which it is easy to remove dirt. These coatings are important and can add value to a car. The fact that a polymer chemist would spend ten years working on one of

these coatings shows that these products can make money (assuming that private funds were used).

However, many cleaners are mostly used by mechanics and are less glamorous. Carburetors and chokes can become clogged with varnish or carbon. These materials come from incomplete combustion or exposure of oil and gasoline to heat. Over time, the organic crud can clog narrow passages and cause problems.

A car mechanic will often clean and unclog the engine with a solvent. Following the rule of "like dissolves like," these solvents are nonpolar (another word for "oily"). These nonpolar solvents are able to dissolve the oily crud in a carburetor or choke. A cleaning job like this can pay for itself if the power and fuel economy of the engine improve.

Cleaners for the carburetor and the choke are made to clean those parts of the car. Most of these cleaners leave behind a dry lubricant to reduce the wear on moving parts while the engine is running. While this is very nice when cleaning the carburetor, these cleaners should not be used to clean electrical components. The dry lubricant can conduct electricity and cause short circuits.

The cleaner for the carburetor also should not be used to clean the brakes. Brakes work by the friction of two surfaces rubbing against each other. This friction converts mechanical energy into heat energy. Now, just imagine what would happen if a carburetor cleaner were used to clean the brakes. Any crud would be removed. However, the dry lubricant would remain on the braking surfaces. The surfaces would just slide past each other with little heat being created. The car would hardly slow at all.

As you may imagine, it is worth the extra money to buy a special type of cleaner for the brakes that does not leave a lubricant behind. Cleaning the brakes can often stop the squeal caused by dirt in the brake system. Of course, if the squeal is caused by metal rubbing against metal, cleaning the brakes will not cause the brake pads to grow back!

Cleaners for the electrical system produce a dirt-free and oil-free surface on metals. These cleaners remove oxidized metal (such as rust on iron). They also can remove oily materials and carbon. However, electrical cleaners do not leave behind a lubricant.

A special type of electrical cleaner is a demoisturant. Demoisturants remove water from the surfaces. In a chemistry lab, a common chemical used to remove moisture from glassware is acetone (a chemical also used to remove nail polish). The acetone is poured on a wet

surface and it dissolves the water. The watery acetone solution is then removed. The acetone still clinging to the sides of the glassware quickly evaporates to leave a dry surface.

Acetone would make a poor demoisturant for electrical systems because acetone catches on fire easily. The ones used for cars are not flammable and will not conduct electricity.

Degreasers are another type of cleaner used to remove greasy materials from the outside of the engine or the chassis. Some of the degreasers are detergent-like and can be rinsed off with water. Others are less soluble in water and need to be rinsed off with organic solvents.

## Deicing Windows

The best way to deice windows is probably the way used by most people. This method is to let the car's heater run for 10 to 30 minutes to warm up the inside of the car and melt a thin layer of ice on the windshield. An ordinary ice scrapper can then remove the rest of the ice.

Other methods do not work as well. Following the example of road crews, you might decide to pour salt on the windows. Unless the ice is thin and the temperature is high enough (such as 20 degrees Fahrenheit), the ice will not melt completely or will melt slowly.

Many people try using heat to melt the ice. Using a hair drier is the safest way to apply heat. Even so, this can be frustrating or even costly.

The chemical concept of a heat of fusion explains why this method does not work. It takes a huge amount of heat to change ice into water. It takes as much heat to change one ounce of ice at 32 degrees Fahrenheit into one ounce of water at 32 degrees Fahrenheit as to heat one ounce of water at 32 degrees Fahrenheit to 176 degrees Fahrenheit. That is a lot of heat from a hair drier. Even worse, the ice closest to the heat will protect the ice below because ice is a good insulator of heat. A person could stand there for hours melting one thin layer at a time.

Finally, some people try to clean off the windows with hot water. The hot water takes a while to melt past all the layers of ice that protect each other. Once the protective ice is gone, if the window beneath the ice is heated unevenly, the uneven expansion of the window can result in great stress inside the glass. This stress can cause a window to shatter.

The most popular method of deicing avoids these problems.

## Driving

A well-driven trip should be forgettable. Road hazards should be seen as far ahead as possible and avoided. Coasting to a stop at red lights saves fuel but is less exciting than squealing to a halt. A gentle start from a standstill wastes less energy than "peeling rubber." (Also, it is safer and reduces wear on the tires.) Avoiding lane changes saves fuel because it helps the driver maintain a constant speed. Playing the radio is a cheaper way to keep the trip interesting.

### Attitude

For those people who have driven a car for over a year, the most important characteristic of their driving is their attitude. (For those just learning how to drive, the most important characteristic is how well they remember which is the gas pedal and which is the brake!)

Attitude is reflected in how much time drivers allow to reach their destination, the way they treat other drivers, and the number of chances they take. A leisurely, easy-going attitude to driving tends to produce fewer accidents and saves gas. Letting other drivers pass who are in a rush to get somewhere reduces the chance of an accident. A good way to save gas is to pull into the slow lane, set the car on cruise control, and watch those who are always late exceed the posted speed limits.

### Planning trips

The best way to save time and money on transportation is to carefully plan trips before starting them. If you can cut a few miles from each trip, the savings in travel time and gasoline bills are immediate and sizable. Because of this, reducing the number of miles driven is more important than increasing the miles per gallon — although that is also a worthwhile goal.

If you have to visit several places, try to plan one trip rather than several short trips. Starting and stopping a car can cause engine wear as the oil takes some time to lubricate the engine parts. Also, a cold engine is not as efficient in burning the fuel as a warm engine because combustion is more efficient at higher temperatures. To benefit from a warm engine, plan trips where the first stop is the longest distance away from the starting place.

Plan trips so that the total distance covered is as small as possible. If given a choice between two routes of similar distance, pick the route

with the fewest number of stops using good roads. Ideally, the roads should be as straight and as level as possible.

It is acceleration that costs most of the energy — not velocity. Without air resistance and friction, it would take no fuel to travel along a straight and level road at a constant speed. This is how spacecraft can travel so far at such high speeds with so little fuel.

Every stop costs waiting time and energy to accelerate from a standstill. Climbing hills requires energy to accelerate against gravity. Rounding a curve requires energy to change the direction of the car. For those reasons, highway travel requires less fuel. It is reflected in the higher MPG numbers for highway driving.

Plan your trips for when the traffic is light. More cars on the road usually means more stops and waiting time. Also, listen to traffic reports when traveling. It can help you avoid major traffic jams. Frequent travelers use citizen band (CB) radios for that reason. If you spend more than an hour or two per day on the road, it might be worth buying one to alert you to road hazards.

Ask yourself before each trip, "Do I really need to drive?" Taking a bus or a plane is sometimes cheaper because one vehicle can carry several people at the same time. Car pooling is cheap for the same reason. A phone call can sometimes save a trip with great savings (about 25 cents per mile plus driving time). If you need exercise, a bicycle can sometimes be used for short trips. However, bicycling is more expensive when food costs and time spent traveling are factored in.

Pleasant weather is safer and cheaper for driving. Cold weather makes the engine less efficient. Rain or snow tends to reduce miles per gallon. Strong winds can make the engine work harder — especially head winds.

Plan shorter trips. If there is a store nearby and one across town, consider travel expenses before shopping across town. Likewise, if given a choice between visiting an amusement park in another state and one nearby, consider the travel costs along with other factors (such as the height of the roller coasters and the length of the lines).

## Under-Inflated Tires

Tires roll more smoothly when they are fully inflated. Under-inflated tires can cost up to one mile per gallon and can cause traction and tire-wear problems. Some experts suggest checking tire pressure with

every fill-up of gasoline. Many mechanics will inflate the tires when the car is brought in for an oil change.

Be sure that the tires are cool when the pressure is checked and air is added. After driving for a while, especially on a hot day, friction on the tires can heat up the air inside. Gases expand when heated, but the walls of a tire keep the gases inside from expanding very much. If gases want to expand but are prevented by a solid wall, they put a lot of pressure on that wall to try to get it to move.

Hot air inside a tire causes it to show higher than normal pressure on a tire gauge. The pressure goes up by roughly one psi (pounds per square inch) for every ten degrees above the outside temperature.

Both over-inflation and under-inflation can cause problems. If a tire is over-inflated when the tire is cool, the buildup of pressure when the tire warms can cause problems such as poor traction or even tire failure.

## Some Modern Materials Used in Cars

Modern cars include a lot of plastics and composites. Composites are just solid mixtures of materials; for example, glass or carbon fibers in plastic. Many of these new materials have more strength than steel, are lighter, and do not rust. However, they tend to cost more if they are damaged in a minor accident because they do not bend back into shape as easily as steel does.

Aluminum is also replacing steel in some parts of the car. It is lightweight, which increases acceleration and gas mileage, and does not rust like steel or iron. Instead of rusting through, aluminum quickly reacts with oxygen to form a thin coat of ceramic that protects the rest of the metal. Aluminum corrodes more slowly than iron for that reason.

## Sunlight on a Car

Most paints will fade when exposed to ultraviolet (UV) light from sunlight. The UV radiation promotes a reaction between oxygen (from the air) and the paint that bleaches the paint's color. One strategy is to protect the paint with a wax that prevents UV light from reaching the paint. Another strategy is to buy a white car.

A common problem from sunlight on a car is the greenhouse effect. When sunlight goes through the windows of the car and is absorbed in the interior of the car, it changes from visible light into heat. Glass does not let

heat out quickly because glass is an insulator. Energy passes through the windows on a sunny day, but the resulting heat is kept inside the car. The temperature inside can increase rapidly. This is especially true for dark cars that absorb sunlight more completely.

The heat can hurt animals or people inside the car. Rolling down one or more windows lets the heat out and can save the lives of pets or children inside the car. Of course, a surprise rainstorm can make the inside of the car wet.

Buying a light-colored car reduces the greenhouse effect because more of the sunlight is reflected rather than turned into heat. For this reason, a white car often needs less energy for its air conditioner.

## Possible Cars of the Future

Predicting the future is tough. However, procrastinators are often good at it. By waiting until June, it is possible to achieve great accuracy in predicting events for the first part of the year. However, the accuracy about the last half of the year tends to be poor.

The end of this chapter looks at two alternatives to modern cars. Neither diesel nor electric cars look good when compared to gasoline-powered cars. However, the technology might improve, or people could be forced to use them anyway. These few pages are just to let the reader know what might be coming. I shall wait a while before predicting what will actually happen.

### Diesel

In the United States, diesel engines are not popular in cars. In the 1995 model year, only one new diesel-powered car was introduced for sale throughout the country — the Mercedes-Benz E300.

It could go about 750 miles between fill-ups. This huge range allowed drivers to refill at truck stops less often. Also, the car would be less likely to run out of diesel fuel when traveling in strange places away from truck stops.

Diesel-powered vehicles run poorly on regular gasoline. Gasoline is far more volatile and is almost certain to cause engine knock that could ruin a diesel engine. All diesel-powered cars, trucks, and buses need diesel fuel that is found at truck stops but only rarely at gas stations. The lack of fuel is a major reason why diesel-powered cars are unpopular in the U.S.

In contrast, European countries have many diesel cars on the roads. The reason for this has a lot to do with taxes. Gasoline in Europe is often taxed 400%! This means for every Deutsche Mark that goes to the filling station; four Deutsche Marks go to the government of Germany. To find this sort of tax rate in the United States, it is necessary to look at "sinning" chemicals such as alcohol or cigarettes.

With fuel prices in Europe kept artificially high, diesels look good. While gasoline-powered engines are only about 35% efficient, diesel engines are about 40% efficient. Some new diesel engines are up to 45% efficient, and this can produce high mileage ratings. Some diesel-powered Volkswagens can achieve 62 MPG. When gasoline costs $5 per gallon, this sort of fuel economy can pay for the car!

From a "green" standpoint, diesel engines are neither better nor worse for the environment than gasoline engines. Gasoline engines tend to produce gases such as hydrocarbons and carbon monoxide. Diesel engines tend to produce soot (mostly carbon) and products from the reaction of nitrogen with oxygen. (Both nitrogen and oxygen are gases found in air.)

Some green people claim that diesel engines are greener because they emit less carbon dioxide. These people claim that carbon dioxide causes global warming. However, there is little evidence of a warming trend, and carbon dioxide is not the major greenhouse gas — water vapor is.

Still, if the greens take power or if gasoline prices go up, diesel engines may become more popular in the United States.

### Electric cars

Some common complaints about electric cars are that they drive like golf carts, they need to be recharged too often, and there are no filling stations for electric cars. However, one old complaint about these cars no longer rings true. Early electric cars were slow compared to most other cars. Modern electric cars can meet or exceed the posted speed limit — at least when no cops are watching! A test car has exceeded 183 miles per hour using only battery power. That is fast enough to get thrown into jail anywhere in the United States!

Still, there are other technical problems with electric cars that remain to be solved. For example, batteries are often the only source of power in these cars. How can the batteries power the heater or the air

conditioner without running out of power for pushing the car forward? Many engineers have spent many hours working on this problem.

The best solution so far has been to use the energy that would normally be lost as heat. When parts of the car rub together, friction converts some of the mechanical energy into heat. Engineers at Mercedes Benz have taken this heat and used it to warm the inside of the car when it is cold out. In the summer, this heat supplies energy to a refrigeration unit.

It turns out that it is easier to warm the passengers than to cool them. Only a small amount of warm, outside air can be allowed into the car before the temperature starts to rise. The closed-in air creates problems. Secondhand smoke can easily become thirdhand or fourthhand (assuming you are an octopus) when the smoke cannot escape from the car. Also, moisture from the breath of the passengers can accumulate causing the windows to fog up.

Mercedes Benz has been trying to solve the fogging problem by installing an air drier (a dehumidifier) that uses a type of chemical called "zeolites." Zeolites act like sponges with tiny pores. They look like little pebbles but have a rather low density because so much space in them is filled with air. When moist air gets inside these pebbles, the zeolite traps the water in the air. Blowing moist air through a container with these zeolites lets the air through but traps the moisture before it can condense on the windows.

Engineers can now make electric cars that burn gasoline. While this is not a nature lover's dream, it can help solve the problems resulting from power draining on long trips or in 100-degree weather (degrees Fahrenheit — 100 degrees Celsius would be hot enough to boil water).

# Chapter 7

# Chemicals around the Home

Home ownership is a tough job that requires lots of money and good problem-solving skills. It could well be the subject of a book by itself. Actually, many magazines and books about housekeeping and home improvements sell reasonably well. There are also videos and cable TV programs on the topic. This chapter is a more or less random sampling of some tips on the subject that involve chemistry.

## Composition of Laundry Detergents

A detergent must contain at least one surfactant (short for "surface active agent"). Surfactants dissolve the greasy spots. Good detergents often use more than one surfactant because two surfactants tend to "gang up" on dirt and clean better than just one. (Note that "gang up" is a political rather than a scientific term.)

Most of these surfactants are either anionic or nonionic. Anionic surfactants go into solution because they fall apart in water, like a salt, to form ions. Anything dissolves in water when it falls apart to form ions. At a very small level, there is a good reason for this. Ionic solutions conduct more electricity than nonionic ones because a flow of ions can carry a charge.

Nonionic surfactants do not fall apart in water. While they dissolve in water, they do not turn into ions. Nonionic surfactants look the same as anionic surfactants when they dissolve in water. However, nonionic solutions conduct less electricity.

Nonionic surfactants dissolve in water because they are polar — another way to say "water-like." Water-like chemicals dissolve in water.

As a rule, "like dissolves like." Another example would be alcohol, which is polar, dissolving in water. Beer drinkers can relate to that example better.

Both common types of surfactants work by first dissolving in water. The wash water carries the detergent to where the greasy spots are. Because the surfactant is somewhat grease-like as well as being water-like, it can dissolve grease. With the grease dissolved in the wash water, the remaining part of the spot is easier to remove. Regular water can then rinse away the wash water so that the grease does not end up back on the clothes.

Detergents also need "builders." The most common builders used to be phosphates. These chemicals buffered the wash water at a good acidity level. (A buffered solution takes lots of acid or base to change the pH.) Phosphates also kept impurities in hard water from reacting with the surfactant to form a scum. They also prevented clay particles from soiled clothing from dropping back onto the washed clothing. Even better, the phosphates used were cheap and about as toxic as table salt.

The fact that phosphates were nontoxic is why they are no longer used in places like Ohio. The water from washers is usually dumped into sewage systems without treatment and from there it goes into rivers and lakes. Water from farms also goes into the rivers without treatment.

Between the phosphorus-rich phosphates from laundry detergents and the nitrogen from fertilizers, plant life (such as algae) in rivers and lakes grew rapidly. Soon, there was so much plant life that the fish started to die. Before long, Lake Erie had no fish in it.

Dead lakes are very unpopular. The politicians had three main choices. They could outlaw nitrogen fertilizers, require that the sewage water be treated, or outlaw phosphate builders. They chose to outlaw phosphate builders. Now, three types of chemicals are added to detergents in place of phosphates — a buffering agent, a stabilizing agent (protects against hard water), and a soil-suspending agent (keeps the clay from falling back onto the clothes).

Inert fillers, such as sodium sulfate, help detergent powders remain free-flowing. Because it costs money to ship big boxes, shelf space in stores is quite precious, and buyers have limited storage space, less filler is being added to concentrated detergents.

Fluorescers are added to make yellow fabrics look white. These chemicals absorb ultraviolet light and emit (give off) blue light. Yellow

fabrics do not emit much blue light, but white fabrics give off blue light (along with every other color). When the colors emitted from the yellow fabric are mixed with the blue light from the fluorescers, the color looks white. More than one fluorescer is needed because different fabrics, such as nylon and cotton, need different fluorescers.

Most people expect some foam from their detergents. These little bubbles assure the users of the product that it is doing something. However, bubbles can sometimes reduce the cleaning power or cause other problems. The result depends on how the product is used.

For spot cleaning with very little liquid (such as carpet shampooing), the bubbles of foam serve an important role by lifting the dirt. The bubbles of foam containing the dirt can be washed or vacuumed away.

For many purposes, the foam is not needed. For example, there is enough water in a washing machine to remove the dirt without any suds. Suds can even make the washing less effective if it softens the impact against the sides of the washer. This problem with suds is most important for side-loading washers. In top-loading washers, the movement of the washer just mixes the wash water with the clothes. In side-loading washers, the movement of the washer pounds out dirt.

Many detergents also contain bleaches. These chemicals, such as sodium perborate, oxidize colored stains while also fading the colors of the clothing. Colors fade when exposed to sunlight and oxygen even without bleach, but one treatment with bleach can fade colors as much as a year in bright sunlight would. Because bleach acts like oxygen gas when fading colors, the action of bleach is called "oxidation." (There is a more precise definition, but this will do in most cases.)

Sodium perborate requires hot water to activate it and begin the oxidation process. This is why clothing should be separated on the basis of color. White clothing goes into hot water to be bleached. Colored clothing should be washed in warm or cold water. Washing colored clothing in hot water could lead to rapid fading of the colors.

Bleach should not be mixed with other cleaners because toxic gases can be formed. For example, mixing sodium perborate with chlorine (another oxidizer) can cause problems. Mixing hypochlorite salts (another type of bleach) with ammonia is also unwise.

Some detergents contain enzymes. Enzymes are proteins that can quickly remove certain types of stains. For example, a protein stain may

react slowly with water to form amino acids. Around the right enzyme, this slow reaction with water may become more than a million times faster. Because amino acids are more soluble in water than most proteins, the spot quickly dissolves in the wash water.

Each enzyme destroys only one type of soil. The most common enzymes in detergents are proteases that remove protein stains. Other enzymes include: amylases (digest starches), cellulases (digest cellulose), and lipases (digest fats). Oddly, cellulases can be used on cotton, which is mostly made of cellulose. The cellulases remove tiny fibers of cellulose that would otherwise cause cotton fabric to become gray and stiff. Note that the names of most enzymes end in "ase."

One problem with enzymes is that they can cause allergic reactions. There may be an initial period when the person can be around the allergen (such as pollen or an enzyme) with no problem. However, once the person becomes allergic to an enzyme, it can cause problems such as rashes or asthma attacks. Switching to a brand of detergent with different or no enzymes can help.

## Fabric Softeners

Fabric softeners are similar to anionic surfactants in that they form ions when they dissolve in water. However, the charge on fabric softeners is cationic rather than anionic. Cationic ions are positive while anionic ions are negative. As a rule, "opposite charges attract."

This is why most fabric softeners are added in the rinse cycle or in the drier rather than when the laundry detergent is added. Because they have opposite charges, the two liquids would react with each other. The greasy portions of the fabric softener and detergent would combine to make a material too greasy to stay in water. A greasy scum would drop out of solution and dirty the clothes.

Those fabric softeners that work in the rinse cycle are soluble in water. Those that work in the dryer are insoluble in water. To save money, use whichever fabric softener is cheapest per load. To save time, it would be wise to keep some of the dryer sheets around. Fabric softeners that work in the dryer can reduce the time spent waiting for the rinse cycle. For people who could not care less about a little static cling, fabric softeners are not needed.

## Dish Washing Detergents

Cost per fluid ounce of dish washing detergent is not a good measure for comparison shopping. Some cheap brands can be very dilute. A concentrated small bottle takes up less space and can clean more dishes than a dilute large bottle. If you like it dilute, you can always add tap water to a concentrated brand.

The chemicals used in detergents are carefully matched to their tasks. A major difference between liquid dish washing detergents and liquid laundry detergents is that dish washing detergents do not have inorganic builders.

Machine dish washing detergents are more corrosive than the manual type. This is largely due to sodium metasilicate. The toughest job for chemists formulating these detergents is to avoid corroding aluminum, plastic, and glass. If you notice that your drinking glasses are getting thinner and your aluminum pans are becoming lighter, it may be time to switch brands of dishwasher detergent.

The latest type of machine dish washing detergent is a liquid. Thickeners were added to help the liquid stay in the compartment designed for powders. Compare the liquids to the powders based on the number of loads of dishes they will do.

### Washing dishes

It is no accident that dishwashers employ sprays of hot, soapy water. Heat usually makes solids more soluble. Soap makes oily materials dissolve. A stream of water washes away soluble waste more quickly and completely than just putting the dish in a soapy tub. If you do not use a dish-washing machine, using hot, soapy, running water can clean dishes fast and well.

## Mixing Cleaners

Many cleaning solutions can be mixed. For example, many brands of laundry detergent can be mixed with other brands of detergent without ill effects. However, some types of cleaners can react with each other to form heat or foul gasses.

When bleach and ammonia are mixed, a gas made of chloramines can form. This gas can stink up a house and is quite painful to breathe.

Some popular brands of drain cleaners cannot be used with each other. Many types of drain cleaners use strong bases such as sodium hydroxide (also called NaOH or soda lye). When powders containing sodium hydroxide are used to clean drains, a cake of soda lye can form in the drain pipe. The cake of soda lye does little harm by itself. (It just eats away at the pipe a little.)

However, when a liquid drain opener that uses sulfuric acid goes down a drain with a cake of lye in it, the acid will react with the soda lye. This reaction can generate enough heat to boil water. Hot sulfuric acid often travels back up the drain in a good imitation of "Old Faithful." The acid from the geyser is able to destroy metal or flesh.

## Lawns and Gardens

An important virtue when planting seeds is patience. This is especially true in the spring. While a seed may take ten days to germinate (grow a sprout) in a summer month, it may take a few extra days in cool weather. The chemical reactions that are responsible for life occur more slowly at cool temperatures. Life-forms that do not regulate their own body heat, such as bacteria, reptiles, and plants, grow more slowly when it is cool outside.

### Fertilizers

Basic nutrients needed by plants include: calcium, magnesium, nitrogen, phosphorus, potassium, and sulfur. Also needed by the plants in trace amounts are boron, chlorine, cobalt, copper, iron, manganese, molybdenum, sodium, and zinc. Plants also need carbon dioxide from the air.

Nitrogen is very common. About 78% of air is composed of this gas. However, neither humans nor plants can use nitrogen gas for nutrition. Bacteria in the roots of peas, beans, clover, and alfalfa can take nitrogen from the air and convert it into a form (ammonium or nitrate) that plants can use to grow. Nitrogen-poor soil can be improved by planting one of these crops. This can reduce the need for fertilizer.

### Pesticides

Pesticides include those chemicals that kill insects (insecticides), fungus (fungicides), weeds (herbicides), and rodents (rodenticides). The key is to kill the pest without killing either someone next door (homicide) or yourself (suicide).

Toasting makes the carbohydrates in the bread easier to digest, but toasting can also cause the loss of some of the bread's protein and vitamins.

## Oats

Among the cereal grains, oats have the highest amount of protein and are high in carbohydrates. This makes them quite nutritional, especially for young animals (or children!) who need the protein for the growth of tissue. As the commercial said, "Oatmeal, it is the right thing to do." (I have often wondered why the advertisers did not make that sentence read, "Oatmeal, the right food to eat.")

### Fiber

Fiber is just the part of food that is not digested. The body does not use fiber for energy or building body tissue. However, fiber may help fight diseases such as diabetes, constipation, gallstones, ulcers, colon cancer, and breast cancer.

To pack as much nutritional value into a food as possible, it used to be thought that indigestible parts of the food could be removed. However, it seems that even those parts of the food are not useless.

Fiber comes in two varieties: soluble and insoluble in water. Soluble fiber slows down the rate at which food is digested. Soluble fiber may also reduce cholesterol levels in the blood. Insoluble fiber lowers the amount of time that food spends in the body while adding some bulk to the stools.

Good sources for insoluble fiber include: wheat bran and the outsides of fruits, beans, and seeds. Coarse insoluble fiber can relieve constipation if mixed with water or milk. Soluble fiber can be found in oats, vegetables, and fruits.

Health effects such as lowering of blood cholesterol is why that actor said that eating oats was the right thing to do. Actually, you might want to eat wheat bran cereal with milk on days when you are constipated.

## Meat

One good reason to eat meat is that it promotes the humane treatment of animals. Farm animals lead cushy lives compared to life in the wild. They are on diets designed for rapid, healthy growth. Sometimes,

the animals are even cared for when they are sick. Contrast this life of leisure with mass starvations and diseases in the wild. So, do not feel bad when you are eating meat. Think of it as helping some poor creature with cute eyes.

To give you an idea of how rich in protein a vegetarian's diet must be, take a look at the composition of lean meat. It is about 75% water, 18% protein, 4% of miscellaneous materials (including minerals), and 3% fat. That is one heck of a lot of protein. There are a number of vegetables that are also high in protein (beans for example). Still, vegetarians must watch their diet closely.

### Meat tenderizers

Meat tenderizers can improve the flavor of many cuts of meat (except maybe filet mignon). These tenderizers are made of enzymes that partially break down the tissue holding the meat together. Filet mignon is already soft enough to eat. If you put tenderizer on it, you may have to use a spoon rather than a knife and fork.

## Beer

The brewing industry in the United States produces huge quantities of beer. In 1992, United States breweries produced almost 25 gallons per U.S. citizen — and most babies do not drink that much!

Although people are drinking less beer than in the past (!), breweries can still use large-scale methods such as huge vats and automated bottling. These methods help keep costs low and the quality predictable. Most of the major brands of beer are brewed in huge factories.

The main ingredients of beer are barley malt, grains (the seeds of certain grasses), hops (dried flowers of a vine plant), and water. Beer makers buy large shipments of grain, barley, and hops from farmers or commodity exchanges. Malt is made by soaking grain (usually barley) in water and causing the seeds to sprout. The baby plants are dried to become malt and sometimes powdered. Malt is rich in various enzymes such as diastase that can quickly convert starch into sugar.

(Note that powdered malt is sometimes sprinkled into milk to create malted milk. The enzymes from malt can help people with digestion problems.)

However, the key ingredient of beer is water — although a case could be made for alcohol. Good beer is mostly water, and water is needed

in the factory to heat and cool the beer. For every gallon of beer, the brewery uses ten gallons of water.

All the ingredients are thrown into a large vat, and yeast feed on the carbohydrates from the grain. Yeast can change sugars and starches into ethyl alcohol. This process is called "fermentation." When a desired level of alcohol is reached, the beer is purified, canned or bottled, and heat-treated to kill germs.

One large brewery avoids heat treatments by using special filters. Germs are much bigger than most chemicals. The germs are trapped on the filters while the rest of the beer goes through the filters' pores. Some people prefer the taste of beer that has never been exposed to heat. Heat can cause a series of chemical reactions that produce different flavors in the beer. Filtering avoids these changes in flavor.

## Strong Beverages

Hard liquor usually starts with the fermentation of plant material. Each type of drink starts with its own mixture of vegetables such as potatoes, corn, rye, or barley. Yeast will eat many types of plants, but there is only a small market in the United States for drinks made from seaweed. (However, that may be an idea for some health food stores!)

A poor quality wine or beer is usually the result of the yeast fermentation. The yeast cannot bring the alcohol content of the mixture much above 20%. After a certain point the alcohol will begin to kill the yeast for the same reason that pure alcohol can be used to disinfect wounds.

To increase the alcohol content above 100 proof (50% alcohol), the crude mixture is boiled and droplets rich in alcohol are condensed (changed from a vapor into a liquid) in a process called "distillation." Most of the alcohol evaporates before the water and vegetable matter vaporize. By collecting drops from early in the distillation, the alcohol can be concentrated from about 20 proof to over 160 proof (80% alcohol).

Stainless steel or copper vats are often used for the distillation. The distillate (the condensed droplets) is placed in wooden barrels and aged to give the liquor its flavor. It is the barrels that give the drink most of its flavor. The length and quality of aging can make the difference between good and bad liquor. Wide temperature ranges while aging expands and contracts the barrels and brings more wood chemicals into the liquor.

The aged liquid from the barrels is diluted with water and sometimes sugar or honey is added. The quality of the water is important (just as with beer). Traces of metal in the water can ruin a liquor.

Alcohol is one area where saving money is not a big deal for most people. They are willing to pay a little extra because they consider it a luxury and not an everyday expense. Lawmakers have used this to raise taxes on alcohol.

### The measure called "proof"

Using the American system, whisky that is 160 proof is actually 80% grain alcohol. To find the percentage of alcohol, just divide the proof number in half. Alcohol of 100 proof is really 50% ethyl alcohol by volume. That is, 100-proof liquor is half pure alcohol and half flavored water. Using this system, gunpowder soaked with 114-proof liquor will ignite.

The British use this gunpowder test to set alcohol at 100 proof. Discerning beer and wine drinkers may notice the higher alcohol content of these imported drinks.

As you may have guessed from the gunpowder test, pure alcohol can catch fire. For that reason, do not smoke around liquors over 115 proof in the American system or 100 proof in the British system.

Alcohol absorbs water vapor from the air. Thus, 200-proof (pure) alcohol will slowly drop to 190 proof (95% pure) if left open on a humid day.

### Headaches from alcohol

Drinks such as beer, wine, and distilled spirits can cause migraine headaches. The chemistry is a little complex; but perhaps alcohol triggers a mild allergic reaction that releases histamine. Histamine reduces serotonin levels in the brain and causes a headache.

This would suggest taking an antihistamine to prevent the headache. Unfortunately, the antihistamine may interact with the alcohol to cause problems. Antihistamines and alcohol are both depressants. They could work together to knock someone out.

A possible way to stop the headaches is eating some sugar before drinking alcohol. Sugar often increases serotonin levels and may counteract the histamine.

### Denaturing alcohol

Grain alcohol is sometimes made toxic for tax reasons. By adding some methanol (wood alcohol), drinkers often suffer blindness because most livers change the methanol into formaldehyde. This is a little like putting poison on a child's thumb to wean the child from sucking his or her thumb (not a good idea). A substance has been found that is so bitter it makes alcohol undrinkable without causing blindness. Even so, lots of alcohol are still spiked with methanol.

In any case, check the label. The label will have something like "denatured alcohol," "poison," or "toxic" on it. In its list of ingredients you should be able to find something like "S.D.A. Alcohol 1 (8%)." In English, this means that the product contains ethyl alcohol, but that it is "specially denatured alcohol." The number after alcohol shows the method used to render it undrinkable.

There are around 60 approved methods to denature alcohol. In the example above, method number 1 was used. Method 1 involves adding methanol to cause blindness.

Other methods are used when denatured alcohol needs to be free of methanol. For example, method 40 involves adding a chemical called "brucine" and a little tert-butyl alcohol. Again, these chemicals make the alcohol less appealing to drink.

The number in parentheses is the percentage of ethyl alcohol in the product. This is half the size of the number for proof. Therefore, a mouthwash that is 8% alcohol is 16 proof.

Mouthwashes often use non-denatured alcohol as one of the solvents. However, most people would prefer to drink other liquors. A fresh, mint flavor is an acquired taste.

## Food Poisoning

Some types of food impurities can cause sickness or death. A few examples of this can be found in this section.

### Poison mushrooms

One hobby that can give you food to eat at the end of the day is mushroom hunting. Unlike deer or fish, mushrooms can not run or swim away. Still, if anything, the mushroom hunter must be more careful.

Mushrooms do not like being eaten and some contain deadly poisons to protect themselves.

### Honey

Honey is a type of invert sugar made by bees. However, honey is far from pure. Bees leave traces of pollen in the honey. (Pollen is a material needed to form plant seeds.) This pollen can cause allergic reactions in some people. The pollen from some plants can even be poisonous.

For example, an army of Greeks was intoxicated by honey back in 400 BC because the bees had been gathering the nectar from rhododendrons. Even today, people sometimes become ill by eating honey.

### Toxins from potatoes

Thousands of cases of poisoning from bruised or green potatoes have been reported. This danger is especially great for pregnant or soon-to-be-pregnant women because the toxins can kill fetuses (unborn children). The problem comes from a class of chemicals called glycoalkaloids. Strangely, these chemicals are far more deadly in humans than in other animals. Maybe the potatoes are defending themselves?

### Cancer from food

The current method of testing whether a chemical causes cancer is under attack. Too many chemicals test positive. For what it is worth, scientists at the Food and Drug Administration found that food itself accounts for 98.8% of the cancer risk from food. When the risk of natural spices is added, only 0.2% is due to man-made additives.

### Aflatoxin

Natural food is not always better for people than food from a chemistry lab. A widely quoted example of this is the unwanted food additive called “aflatoxin.” It is often found in foods such as nuts, corn, rice, wheat, and peanut butter. A fungus produces this potent cancer-causing chemical. Without a fungicide protecting the food, it will often be formed.

## Food Containers

With a few exceptions, the trend in food packaging has been away from older materials such as metal, glass, and paper. Plastics (also called "polymers") are used in much of the new packaging.

While glass is still useful when a strong, brittle, translucent (lets light shine through) material is needed, plastics can be tailored to most other tasks. In many cases, glass is too fragile and rigid. For example, a major cleanup job used to be required every time somebody dropped an old soda pop bottle. Besides mopping up the liquid to avoid a sticky floor, the pieces of glass might cut bare feet in the kitchen or a tire on the road.

Polyethylene terephthalate (PET) has been rapidly replacing glass for many purposes. PET will not shatter like glass. It is also lightweight, translucent, somewhat heat-stable, easy to bend, and can be recycled. Because of these properties, PET has become very popular for soda pop bottles. About 2.1 billion pounds per year of PET are produced.

Likewise, paper or paper coated with wax are good for some purposes, but modern plastics are replacing paper in many tasks. For example, polystyrene foam is a good insulator of heat that can slow the transfer of heat through a container. Many polystyrene containers are such good insulators that they can be used to kept hot coffee hot or cold drinks cold. In contrast, waxed paper lets heat transfer through the container so that the food quickly becomes room temperature.

### Kosher packaging

For those people of the Jewish religion, some plastics are now officially kosher. Of course, this does not mean that you should eat the plastics! Instead, it is now OK to buy kosher food wrapped in these plastics.

Some Jewish leaders were concerned that additives made from animal fats would work their way from plastic wraps into the food. This sort of made sense in a way. It is true that many plastics use salts of fatty acids such as calcium stearate to make the plastics more flexible. Stearic acid is a type of fatty acid often found in animal fats such as beef fat. Calcium stearate is just the calcium salt of the acid.

When it is put into a plastic, calcium stearate acts as a plasticizer to lubricate the inside of the plastic and help the plastic bend. (Plasticizers also help keep vinyl soft.) While flexible plastics are nice for food

packages, the use of plasticizers from animal fat created a religious problem for some Jews, some Muslim groups, and some vegetarians.

To solve this problem, Solvay Polymers made salts of stearic acid that come from vegetable sources rather than animal fat sources. These fatty acid salts from vegetables can be used in place of the other fatty acid salts. Just like a trained chemist, the plastics cannot tell the difference.

### Advantages of plastic wrap

Plastic films such as Saran wrap have some advantages over paper. The films are transparent (no guessing at what is in the bag), lightweight, puncture-resistant, free of odors and flavors, nontoxic, and transmit moisture very slowly. By using these wraps and bags, food stays moist in a refrigerator or freezer for a long time. Also, you can store dead skunk next to Limburger cheese with no mixing of flavors.

### Aluminum foil

Aluminum foil can also be good for wrapping. It is mostly aluminum metal with a thin coat of aluminum oxide to protect it from water. It can withstand both very low and very high temperatures. It conducts heat well — making it good for cooking or freezing. Like plastic wrap, it seals in odors, flavors, and moisture.

Aluminum gives off sparks (called "arcing") when foil untreated with a special plastic coating is placed in a microwave oven. Also, foods with high pH (basic) or very low pH (acidic) can dissolve aluminum. The term for materials that can react with either acids or bases is "amphoteric." Foods with a sour taste (low pH) may be more safely stored in plastic wrap.

Aluminum is not ferromagnetic like iron. In the early 1960s opening a can of frozen orange juice was an unwelcome chore. At the time, the cans had aluminum ends. When the can opener was finished, the lid would fall into the can and was sometimes difficult to fish out. With modern cans that is no longer a problem. (Long live technology!) The canneries ran into trouble because the magnet on automatic can openers would not grab the lid as it does lids made of steel.

## Freezing and Refrigerating

Refrigeration slows the growth of germs. It also slows chemical reactions such as oxidation that can make food smelly or toxic. Freezing

food not only slows the growth of microorganisms because of the cold but also removes the water that the germs need to live. Freezing is a good method for long-term food storage.

### Freezer burn

Freezer burn is caused by loss of water from frozen food. Even at very cold temperatures, water can go from the solid phase (called ice) into the gas phase (called water vapor). This process is called sublimation. Unprotected foods will lose water in this way from exposed surfaces. Aluminum foil or plastic freezer bags can slow the loss of moisture in the freezer.

The loss of moisture that causes freezer burn makes it easier for the food to react with oxygen in the air. For this reason, the surface of the food is often the most damaged part. Try cutting into the food. You may find that the freezer burn can be cut away and the center of the food salvaged.

### Refrigerator and freezer temperatures

The temperature setting on refrigerators and freezers is a compromise between energy costs and costs from food spoilage. If the freezer is set just four degrees Fahrenheit (F) too low, it increases the cost of refrigeration by 10%. A freezer setting of 0 F should be OK while 34 to 37 F is a good range for the refrigerator. (Of course, the refrigerator should be above 32 F as water would start to freeze below that!)

Almost all toxin-producing germs are in a dormant state at 32-38 F. If you make sure your refrigerator is in this range, it will reduce your chances of food poisoning as well as make your food last longer.

### Frozen dinners

Frozen dinners usually cost less than a restaurant meal and require little time to prepare. They are as nutritional as most home cooked meals. These packaged dinners are a good way to avoid cooking and cleaning dishes. Married couples can even cook together. The wife can pick out the dinner, the husband takes it out of the box, the wife removes the foil from the dessert, the husband pokes holes in the rest of the foil, and the wife can put it in the oven.

You must follow the instructions on the package exactly. If you cook the food too long, the color and texture of the food will go bad on you.

## Other Methods of Preserving Food

### Irradiation

Irradiation is the use of high-energy emissions from radioactive sources. Sealed containers of food can be sterilized using this technique. The amount of radiation can be carefully controlled to kill insects, molds, or bacteria. The energy of the radiation is set at a low enough level so that the food does not become radioactive.

Still, irradiation has had its share of problems. Bacteria sometime enter the package after being treated (really a problem with the package). Oxygen in the package can react with the food after its treatment to spoil the food. Also, Clostridium botulinum often survives radiation to cause botulism. Note that this germ also causes problems for pasteurization (heat-treating food). Check irradiated food carefully before buying or eating it.

### Dried food

By drying food, the moisture needed for the growth of microorganisms is removed. The key to preserving the food is to keep it dry. So, if your trail rations get wet, be sure to either eat them quickly or dispose of them.

Dried food can taste very good and often does not require refrigeration. However, dieters should be aware of how dried food is made. A regular bit of food — such as a grape or a sliver of meat — has the water removed from it. Water has no calories. All the calories of the original food are still in the much smaller and lighter dried food. A pound of dried meat has far more calories than a pound of meat directly from a cow.

### Natural food preservatives

Some foods such as red raspberries and strawberries are best stored packed closely together and in an air-tight container. These berries give off chemicals to slow the growth of fungi.

Many other living things also make chemicals to fight off natural predators. These chemicals are usually "secondary metabolites" — meaning, chemicals produced by the life form not directly needed for life processes. Most of the pesticides in plants are of this type.

### Chemical preservatives

Many of the preservatives added to food either slow the growth of germs or protect the food against oxidation. Various acids, salts, and sugar have been used to slow the growth of germs. BHT and BHA along with vitamins such as A, C, and E are antioxidants. Antioxidants work by reacting with oxygen before it can react with the food.

## Miscellaneous Topics

### Caffeine extraction

Americans average 211 mg/day of caffeine (about seven-thousandths of an ounce). The caffeine comes from coffee at about 60-200 mg/cup, cocoa at 5 mg/cup, chocolate at 6 mg/oz, cola at 35-55 mg/can, and tea at 30-50 mg/cup. Only about 17% of the average American's daily intake of caffeine is from soft drinks. Most of the caffeine is from coffee.

While most Americans consume caffeine every day, many people are trying to reduce their intake of caffeine. Others wish to avoid caffeine around bedtime. In both cases, decaffeinated coffee and caffeine-free colas can quench a thirst without creating a caffeine "buzz."

Because coffee beans are rich in caffeine, "extraction" is used to remove (extract) the caffeine from the beans. The extracted caffeine can then be put into soft drinks and alertness pills.

Extraction requires water and an oily solvent. Trichlorethane is often used as the oily solvent for extracting caffeine out of coffee. However, carbon dioxide shows some promise as a solvent for this technique.

Carbon dioxide is normally found as a gas that comes from the burning of organic materials. Living creatures exhale it when they are burning energy. Also, this gas makes soda water bubbly.

At very low temperatures the gas becomes a solid called "dry ice" that is used to keep things very cold. At atmospheric pressure, carbon dioxide never becomes a liquid. It goes directly from being a solid to becoming a gas in a process called "sublimation." The reason that solid carbon dioxide is called "dry ice" is that it disappears without leaving a liquid behind.

However, it can become a liquid at pressures greater than five atmospheres (five times the pressure at sea level). This type of carbon dioxide is called “liquid carbon dioxide.”

A major use of this type of carbon dioxide is to dissolve organic materials from a mixture. It can be used to decaffeinate coffee, extract the nicotine from tobacco, and remove the bitterness from hops. The liquid carbon dioxide (which can be at room temperature under pressure) is added to the mixture to be extracted. The carbon dioxide has oil-like properties. Therefore, the oils dissolve into the carbon dioxide. When the carbon dioxide is drained away, it takes many oily materials with it.

Carbon dioxide is preferred over other solvents because no trace of it remains after the extraction. At atmospheric pressure the liquid carbon dioxide turns into a gas and bubbles out of the watery solution. If a decaffeinated drink does not taste like the real thing, it is probably not because of leftover solvent. It may be because other oily compounds besides the caffeine were also removed during the extraction.

A variation of this process is to warm carbon dioxide above 82 degrees Fahrenheit and increase the pressure above 73 atmospheres. This type of carbon dioxide is called “supercritical carbon dioxide” and is somewhere between a gas and a liquid.

Supercritical carbon dioxide is a good solvent much like liquid carbon dioxide and can be used for the same purposes. Also, it is used to extract oil out of oilseeds such as soybeans or sunflower seeds. Again, supercritical carbon dioxide has oily properties that can dissolve oils while leaving water behind.

### Cod liver oil

Cod liver oil may bring back some memories to older readers. This stuff was supposed to be good for you, but was not very pleasant.

In the 1840s, two publications came out that claimed cod liver oil was helpful in treating some types of gout, rheumatism, and pulmonary consumption. Even today, doctors argue over whether cod liver oil can treat tubercular diseases.

A foul-tasting variety of cod liver oil has been used as a folk remedy for arthritis and gout for centuries in Norway, Iceland, and Scotland. Modern chemistry (1840s) improved the taste. Before, it was dark, smelly, and foul tasting. Now, it is tasteless.

As the name suggests, it is a fish product. The makers of the oil cut the livers out of cod (a type of fish). They gently heat the livers and extract out the organic chemicals from the organs. The mixture of chemicals in the oil is complex. No one is really sure how it works. Still, with centuries of folk medicine behind it and two scientific papers, there may be something to it.

### Gas production during digestion

Some sugars cannot be digested by people but are favorite foods of bacteria in the human gut. As a result, a lot of gas is produced after a meal including foods such as baked beans.

A method to direct the gases upward in the body (rather than the usual direction) is to eat such spices as ginger, cinnamon, or peppermint. They loosen the sphincter muscle and allow the gas produced by the germs in the gut to pass out the nose and mouth.

Another way to approach this problem is eating an enzyme that breaks down sugars into a form that humans can digest. A product called Beano can be taken in tablet or drop form and reduces the quantity of indigestible sugars in many foods.

### Ice cream substitutes

About 10% of Americans suffer from lactose intolerance to the point where they need special medicine to eat ice cream. Lactose is a type of sugar found in milk and ice cream, but some people lack the enzyme to digest it. Nondairy products such as tofu (which comes from bean curds) or sorbet (which is mostly fruit) do not contain lactose. Thus, these foods can be eaten by people with lactose intolerance.

# Chapter 5

# An Introduction to Health Chemistry

## Do-It-Yourself Medicine

All serious illnesses need care from a doctor. However, minor problems, such as small cuts and mild colds, can often be treated without a doctor. Home remedies can save money and avoid trips to the doctor's office. (Do doctors make house calls anymore?) Still, as with any other do-it-yourself project, expect that it will take more work than relying on a pro. Also, you will make mistakes.

Some of the mistakes are subtle and based on chemistry. For example, some home cures require the drinking of oils such as mineral oil or cod liver oil. After taking the oil for a while, you may develop problems such as rickets, night blindness, and slower blood clotting. You will probably have no clue why these problems are happening and see a doctor because of it.

A good doctor will ask if you are taking any home remedies. When the doctor discovers that you are drinking an oil, the solution to the new problems will appear simple to him or her. Most doctors know that oils dissolve the vitamins stored in body fat. Oils can drain the body of vitamins A, D, K, and E and cause the symptoms of a vitamin deficiency. Note that all four of these vitamins are fat-soluble. (By the way, cod liver oil is not as bad as mineral oil because fish oils are rich in vitamins A and D. However, problems with vitamins K (blood clotting) and E (immune system) can still occur.)

To a doctor, the cause of the problem is simple because the doctor has either seen the problem before or read about it. However, the do-it-yourselfer may not foresee problems like this with home remedies.

### Read the label

While labels tend to be longer now than ever before, it is still important to read them. A magnifying lens seems to help. The labels tell you a significant portion of what has been learned about the product since it first came out. Reading the label will help you avoid the mistakes of other users.

One problem with reading labels is that a single medicine may have many names. The more widely used a chemical becomes; the more names it acquires. The most widely used chemical — water — has many names in every language (ice, water, snow, steam, and so on). Even more recent chemicals can acquire hundreds of names.

Every drug has a "generic" name, but many drug makers will invent their own name for the drug. For example, one drug has a generic name of "Amitriptyline" but has also been called Tryptanol, Laroxyl, and Endep (among other things). Notice that the drug maker's names are easier to remember than the generic name. They want to establish their brand name as a reliable, high-quality source of the medicine.

### Units of medicine

Besides the usual measures of mass such as milligrams (mg) and measures of volume such as cubic centimeters (cc), many drugs from biological sources use the "units" system. Drugs such as insulin can vary in strength from batch to batch. These units measure the relative strength of the batches.

If the bottle of insulin says "U 100," this means that one cc from that bottle contains 100 units of insulin. If the bottle says "U 40," one cc would only contain 40 units of insulin. For a diabetic who needs 100 units once a day, using the bottle of U 100 would mean injections of one cc instead of 2.5 cc from the bottle of weaker strength (U 40).

It is often better to inject small quantities of fluid. Less injected liquid means fewer problems caused by excess fluid at the injection site. Strong batches of insulin (U 100 or more) can reduce the volume of fluid in the syringe. Of course, very small volumes can be hard to measure accurately.

## Aspirin

Aspirin is one of the most useful man-made drugs. Since it was first created in 1899, billions of people have tried it. It is used as an analgesic (pain-reducer), antipyretic (fever-reducer), and anti-inflammatory (reduces painful swelling). Overall, aspirin is also one of the safest drugs.

Still, aspirin can cause problems if abused. For example, small children running high fevers can develop Reye syndrome if given aspirin. Also, it can cause stomach bleeding — especially in large dosages such as two tablets.

This second problem can be helped with a little acid-base chemistry. One of the names for aspirin gives a clue about its chemistry: "Acetylsalicylic acid." While most of the name does not mean much even to a chemist (What does "Kenneth" mean to you?), the last part tells a chemist a lot about this drug.

The word "acid" means aspirin is the type of chemical that dissolves in basic (high pH) solutions of water. Acids dissolve in high pH solutions because they react with bases to form salts that tend to be soluble in water. Aspirin itself is more soluble in fats than in water.

Aspirin goes into the stomach soon after it is swallowed. In the acidic solution of digestive juices, it stays in the acid form and can pass through the fatty walls of the stomach. In going through the walls, it sometimes causes bleeding and stomach pain. Once into the more basic bloodstream (roughly pH 7.4 with pH 7 being neutral), it becomes a salt and water-soluble.

The way aspirin changes from an acid into a salt provides a method for reducing stomach upset. A salt is formed by dissolving aspirin in a basic water solution. Next, the water is evaporated to leave behind the salt. When this salt touches water again, it dissolves and is easy to drink. In the acidic stomach, the salt becomes aspirin again. However, instead of large tablets that might cause bleeding, the aspirin becomes tiny crystals that cause fewer problems.

Another way to reduce stomach upset is to coat the aspirin so that it passes through the stomach without being absorbed. These coated tablets take longer to work.

## Cold packs

Applying a cold pack will often reduce the swelling of an injury and make it less painful. While kissing the injury may be nice, cold is better at soothing hurt nerves.

Ice packs are often the cheapest way of applying cold. Just take a thick plastic pouch, fill it with ice, and apply it to the sore area. An ice pack works because it requires heat for the ice to melt. Heat from the sore area goes into the ice pack to melt some ice. With heat going into the ice pack, the skin temperature around the sore area goes down.

A process such as melting ice that requires heat is called "endothermic." This is the opposite of a process such as fire that gives off heat. Processes that give off heat are called "exothermic."

Melting ice is not the only endothermic process that can be used for cold packs. Because ice tends to melt at room temperature, cold packs that use ice need a freezer nearby. In remote locations, endothermic chemical reactions can provide the cooling instead of ice.

Cold packs that do not use ice commonly work by wetting some ammonium nitrate with water. As this salt dissolves in the water, the bag with the salt solution takes heat from its surroundings. If the sore area is next to the bag, the heat from the sore area will go into the bag. While other reactions are possible, melting ice and dissolving ammonium nitrate are the most convenient.

## Antiseptics

An antiseptic is a chemical that prevents the growth of germs. Perhaps the most common antiseptic is ethyl alcohol. When applied to the skin, it helps prevent infections in wounds, and as a bonus, it helps stop bleeding. A 70% solution of ethyl alcohol in water is a very good antiseptic. For reasons that are not clear, 140-proof spirits kill germs faster than pure alcohol. Isopropyl alcohol also kills germs but is more toxic.

Hexachlorophene is an antiseptic found in some soaps. By reading the label carefully, it is easy to discover if your brand of soap uses it. It can reduce the number and types of bacteria on skin. With fewer bacteria, the spread of diseases by handshakes is less likely. Also, cuts are less likely to become infected. However, this chemical is not to be used for washing infants. It is absorbed through the skin and can harm an infant if used regularly.

Saponated cresol is used in Lysol and Creolin as a disinfectant. It can be used on skin only in very dilute solutions.

Some antiseptics oxidize the areas they touch and destroy anaerobic bacteria (germs that do not breathe oxygen). Iodine tincture combines the antiseptic power of alcohol with oxidizing power of iodine. It can be used for small wounds but is not safe for large wounds. Iodine in glycerin is sometimes used to treat mucous membranes. (An example of a mucous membrane would be the part of the lip inside the mouth. This type of skin is called a mucous membrane because it is usually covered with a thin layer of slime called "mucus.")

The most powerful oxidizing agent used for an antiseptic is potassium permanganate. This chemical has a special place in the hearts of all chemists because it is used to clean glassware. It destroys most organic things on contact. As you can guess, it is used in very dilute solutions as an antiseptic.

The most widely used oxidizing antiseptic is hydrogen peroxide solution. Hydrogen peroxide turns into oxygen gas and water when it contacts flesh because of the rough edges and the presence of metals. (Even in the bottle it slowly decomposes. These bottles often give off oxygen gas.) The oxygen kills germs in a small wound. Also, the oxygen gas cleans the wound with its bubbling action.

Be sure to use the dilute 3% solution and to store it in a dark, cool place. A 90% solution of hydrogen peroxide can be used as rocket fuel!

### Diaper rash

Changing the diapers on a baby is not a thrilling task. However, it keeps the baby's skin free of urea from the baby's urine. Some bacteria will change urea into ammonia and cause diaper rash. While ammonia is good for washing floors, it can make skin red and irritated.

Washing cloth diapers is even less fun. The diapers not only have to be cleaned; they also have to be sterilized by chemicals (and perhaps sunlight). New mothers should consider how much their time is worth. Women busy with their own careers may find that their time is valuable enough to use a diaper service or use only disposables.

Full-time mothers may want to save money by cleaning their own diapers. This is not a simple task because a trace of detergent on a diaper that is not fully rinsed can lead to diaper rash. Also, a diaper not fully sterilized can contain bacteria that cause diaper rash.

The diapers may need to stay in sterilizing solution for about six hours. (Always follow the advice on the package.) The diapers must then be washed and thoroughly rinsed. If they can be dried in bright sunshine, it will help kill many of the bacteria.

Be sure to thoroughly wash after touching the sterilizing solution. It is usually quite toxic and can easily kill a baby.

## Alcohol

"Tolerance" is a word that brings to mind images of people of all races and creeds living in harmony. The chemical meaning of the term is not so far removed from the usual meaning, but there is a nasty catch.

Chemists use the term to describe how well the body can handle a chemical within it. A high tolerance means that a lot of the drug must be present before the body reacts to the drug. Regularly using a drug can create a tolerance for the drug. The catch is that the dosage required to kill does not change.

Thus, the person has to take more of the drug for it to have any effect, but each increase in dosage brings the person closer to an overdose. Alcohol is the most common drug where tolerance is a problem. If you find that you or any of your friends can do great feats of mental or manual dexterity while filled with lots of liquor, there is probably a serious drinking problem. (Also, from a financial point of view, it costs more and more to get drunk.)

### Drug interactions

If you take any medicines, check with your doctor about drinking alcohol. Think about what happens when aspirin is taken with scotch. The contents of the stomach are made more oil-like, and this helps oil-soluble aspirin to go through the stomach lining. As a result, the effect of aspirin is stronger and more rapid. Also, an overdose of aspirin is more likely.

Not every chemical is as safe as aspirin. Many drugs can travel through the lining of gut more quickly with the help of alcohol. Overdoses and death can result.

This is not the only interaction possible for alcohol. Both alcohol and barbiturates (a type of hypnotic once found in sleeping pills) are destroyed in the liver. Taking old-style sleeping pills and alcohol at the same time caused the barbiturates to stay in the body too long. The liver

would work on digesting the alcohol instead of the sleeping pills. The overdose of sleeping pills could be fatal.

If you have a good background in science, you can read about these interactions in a book called *The Physician's Desk Reference*. In general, be careful when mixing drugs and alcohol.

### Curing alcoholism

There is no easy way to cure a drunk. Actually, any habit is easy to fall back into. This is true whether the habit is waking up with the sunrise or drinking too much. Still, chemists can help sometimes if the person wants the help.

Chemists are working on anti-alcohol devices. An old approach was denaturing alcohol. There are now dozens of approved ways to poison alcohol.

One way to help a person quit is using a chemical such as disulfiram that makes alcohol hard to keep down. The drinker eats a little of the chemical. If some alcohol is consumed shortly after that, he or she will become nauseous. Unfortunately, this method is dangerous and has never worked very well.

A company from California is now working on a new drug that promises to make drinking much safer. It is called Detoxahol and works by speeding up the rate at which alcohol is metabolized by the body. The drug works remarkably well in mice — which should lower the number of rodents driving while drunk!

First, the rat is given a strong dose of alcohol. Then the rat is given a dose of Detoxahol that lets the rodent's small intestine digest the alcohol. Soon, the rat is fully sober and ready to drive home. The uses are obvious assuming that the Food and Drug Administration (FDA) approves it. However, the approval process is long and difficult. In the meantime, drunks are left with home remedies such as eating a banana or some sugar that simply do not work.

It normally takes eight hours to metabolize eight units of alcohol: eight cups of beer, eight glasses of wine, or eight shots of whisky. Until the alcohol is removed by the liver, the person cannot safely operate heavy machinery. This is the time to call a taxicab.

## Smoking

If smoking were to be invented today, it would never be allowed to be sold. The tar from burning tobacco causes cancer, and smoking is closely tied to lung cancer. The FDA would consider smoking to be unsafe.

Besides a shortened life span, smokers have to put up with the rising cost of cigarettes and other tobacco products. This is not due to rising costs of farming or producing the tobacco. Rather, the government has had good luck in raising revenue by taxing these products. Whatever the cause of the price increase, smoking has become an expensive habit.

In addition, smokers live with an increased risk of starting a fire. To enjoy tobacco smoke, the tobacco must be on fire. Unless the fire is carefully put out, it could spread to other combustible items such as a bed or a forest.

There is also a social disadvantage to smoking because it can act like a mood ring. The human body closely regulates the level of nicotine (the chemical that causes the smoker's high). Eating or stress can lower the level of nicotine to where the smoker goes into withdrawal, and he or she gets a powerful urge to smoke a cigarette. In a social setting, this is a better clue that the person is nervous than underarm sweat.

If you are a smoker, you should consider quitting. If you are a stubborn smoker who likes smoking, you should consider either switching to a brand rich in nicotine or using a chewing tobacco. It is the nicotine that produces the high while it is the tar that causes lung cancer. By smoking cigarettes rich in nicotine, it is possible to get the high while smoking fewer cigarettes and breathing less tar. With chewing tobacco, no cancer-causing tar goes into the lungs. Both habits are safer than smoking low-nicotine cigarettes.

### Quitting the smoking habit

No matter why a person wants to quit, smoking is a hard habit to break. Only 3% of those who try to quit smoking succeed after one year. Some smokers undergo a major surgery for lung cancer or heart disease and are told by their doctors to either quit or die. An amazing 50% of those people continue to risk their life by smoking.

The first hurdle is the physical addiction. Withdrawal starts within hours and lasts for a week or two while nicotine washes itself from the fat where it is stored. The physical urge to smoke is strong during this period

while the body tries to maintain its old level of nicotine. Symptoms include craving, anxiety, weight gain, insomnia, and a bad mood.

Even after the nicotine is out of the body, the smoker can still feel the need to hold a cigarette after eating or while driving. Habits are hard to break even without withdrawal symptoms. If even a single cigarette is smoked after the physical addiction is over, it is very likely that the smoking habit will return.

Perhaps the best cure currently available is the nicotine patch. The idea is basically to feed the addiction for nicotine while the urge to feel a cigarette in one's hands is treated. Once the nicotine patches are removed, the urge to smoke is less than quitting cigarettes cold turkey. See your doctor!

## Prevention

One of the many famous sayings attributed to Benjamin Franklin is, "An ounce of prevention is worth a pound of cure." (Of course, a chemist would read this as, "28.35 grams of prevention is worth 0.4536 kilograms of cure.") While this statement is insightful, the actual value of prevention depends on how the problem is avoided.

An important concept in modern medicine is preventive care. The greatest success of this method is the smallpox vaccine of 1796. Back then, smallpox was a leading cause of death. The vaccine caused a very mild form of the disease that helped a human body develop its defenses against the real disease. These defenses consisted of special chemicals called "antibodies" that selectively attacked the smallpox virus. Even today, this is the best way to handle a virus. The smallpox vaccine was so effective that the disease is almost unknown now.

Given the great success of vaccinations, you might think that everyone would want them. As it turns out, this is the one area of preventive care where the least money can produce the most benefits. To use Franklin's terminology, "One ounce of vaccination is worth two pounds of cure."

In other cases, preventive measures are not worth as much. For example, some blood tests are overused. It seems that many older Americans routinely test their cholesterol levels. While this can be important for those people who are at risk for heart attacks, the test is done too often on too many patients to be worth the cost. To use Franklin

again, "One ounce of cholesterol testing is worth a pound of cure for some patients, but for most patients, it is worth about an ounce of cure."

Likewise, too many people test their families for lead poisoning. Lead is a material that can cause mental and physical problems, and it is a serious matter. However, many people who are tested are not at risk.

Old paint and old plumbing are usually the cause of the high lead levels. In more innocent days, builders did not know any better than to use lead-containing materials. When little children eat the paint or the whole family drinks the lead-contaminated water, lead levels in the blood can reach toxic levels. However, because of all the publicity this problem has received, too many people are wasting money on blood screening. If you are at risk, then the test is worth it. You might want to ask a doctor if you are. Otherwise, you could be wasting precious ounces of prevention.

Another possibly costly form of prevention is radon detection. Radon is a radioactive gas commonly emitted from granite rock and nuclear reactors. While tightly sealed homes usually have lower energy bills, radon gas from rocky soils can build up in homes with little ventilation. Levels of radon gas in some homes are 40 times higher than levels allowed at nuclear power plants!

The key to wisely using your ounces of prevention is to make sure that you are at risk. If the soil around your home has a lot of granite in it and your home is tightly sealed up, it may be worthwhile to spend the $100 or so needed to test for radon. Also, if you plan to spend hundreds of dollars to seal up your home, it may pay to test for radon after finishing part of the project. This could help you avoid removing some of the sealing material to let the radon out.

In summary, while prevention is important, preventive measures can be wasted if not carefully chosen.

## Treatment for Heart Attacks

Heart problems are the major cause of death in the United States. This is actually a good thing since two major alternatives are famine and war. In the United States, diseases of old age such as cancer and heart attacks are the leading causes of death. Until there is some way to slow the aging process (or start a major war), these diseases will limit how long people can live.

It is ironic that taking steps to prevent heart attacks will increase the chance of dying from cancer! Of course, prevention or treatment of heart attacks will help many people live longer.

A large number of chemicals are used to treat heart problems. To treat heart failure, some drugs will strengthen heart muscles. Different drugs can control irregular heart beats. Blood vessels can be contracted by yet other drugs. Some drugs will expand (dilate) blood vessels. Glyceryl trinitrate (also known as nitroglycerin) is one drug that dilates blood vessels. It is also used as an explosive. Think twice before mugging senior citizens because they might throw their medicine at you!

High blood pressure (hypertension) can cause heart problems. Drug treatments for hypertension are of four types: diuretics that increase the flow of urine, drugs that affect the nervous system, drugs that enlarge (dilate) blood vessels, and calcium channel blockers.

Diuretics treat high blood pressure by reducing the volume of fluids in blood vessels and removing excess sodium. With less liquid to pump through the blood vessels, the heart does not have to work as hard. The sodium level is important because lots of salt in the blood can drive fluids out of the body's cells.

Cell membranes will let water pass through it but keep most other chemicals out. One characteristic of such a membrane (called a semipermeable membrane) is that the water will tend to flow to whichever side of the membrane has the most material in solution. Thus, if blood is rich in salts, then the cells it comes in contact with will lose water until the cells have the same concentration of dissolved materials as the blood. If blood has few salts, the water will flow into the cells.

(This last property can sometimes be used to kill germs. If you place some germs under a microscope and add a drop of distilled water to the slide, you will sometimes see a germ swell and finally pop as the water rushes into the cell. It is kind of entertaining in the same way that pulling the wings off flies is entertaining.)

Calcium channel blockers also involve cell membranes. Since cells normally block just about everything but water, the cells need ways for vital materials to pass through. Special channels through the cell membrane collect calcium ions from the body's fluid as needed by the cell. Calcium helps muscles contract.

Calcium channel blocking drugs block some of the calcium needed for heart contractions. The lack of calcium causes the heart to beat less

strongly and more regularly. These drugs can help treat diseases where the heart beats irregularly or too strongly.

## Antibiotics

Sir Alexander Fleming found the first antibiotic in 1928. However, it was years before any penicillin could be used by the public. He was simply not greedy enough to make a fortune off his discovery.

William Perkin, the inventor of synthetic dyes, and Leo Baekeland, the inventor of an early plastic called Bakelite, are examples of the right way to use a discovery. Both Perkin and Baekeland used their findings to make products that people wanted.

Fleming had some silly notions about wanting to reduce human misery. While that sentiment is better than wanting to rob banks, it hardly inspires other talented workers to work for you. Money does a better job of motivating workers. When Fleming had troubles purifying and testing the drug, he had to shelve the miracle drug for years. As a result, Fleming lost out on his chance to become rich, and millions of people died who could have been saved by penicillin.

Moral of the story: If you discover something of great value, do yourself and everybody else a favor by earning a fortune from it.

Antibiotics are materials made by living cells that kill or slow the growth of bacteria. These drugs have saved millions of lives that would otherwise have been lost to diseases such as pneumonia.

Fleming found that some molds could stop the growth of bacteria and isolated a chemical he named penicillin that killed his cultures of bacteria. Even today, most antibiotics come from molds, bacteria, and yeasts. Large vats of these living things are grown and then harvested to isolate the lifesaving drugs.

These drugs are sometimes chemically altered to produce new drugs. A variety of antibiotics is needed because prolonged use of a single antibiotic can cause two types of problems. First, the germs can become resistant to the drug. A resistant strain of bacteria will happily grow around the antibiotic that it has grown used to. The other problem is that the patient can become allergic to an antibiotic. In either case, another drug would have to cure the patient.

## Allergies

An allergen triggers an allergic response. For example, many people are allergic to pollen. The pollen enters the nose of the person and releases chemicals called "allergens." These chemicals are attacked by antibodies of the immune system. Reactions between allergens and antibodies release histamine that causes the sneezing, runny nose, and watery eyes.

Antihistamines reduce the symptoms of an allergy. They can make life much more pleasant for an allergy sufferer. In some cases, allergic reactions can even cause death. Death from bee stings is usually due to an allergic reaction to the bee's venom.

Finding the cause of the allergy can be simple or hard. If a cat or a flower causes a bout of sneezing or rashes, it is almost a no-brainer. However, an allergic reaction to food may be from anything eaten over the past three days. It can be difficult to tell which food is causing the problems.

One way to find the source of the allergens is to apply a little of the material to the skin and see if a rash develops. This method has a good record of success. Many people are allergic to the same things, and so the doctor is likely to find the cause quickly. Once the cause is found, treatments can begin. If nothing else, a good way to treat an allergy is to avoid the allergen. Antihistamines are great at reducing annoying symptoms, but do not cure the allergy.

Another problem with antihistamines is that they tend to cause drowsiness. This can be a benefit when trying to fall asleep at night, but during the day or working the night shift at a nuclear power plant, it can be a problem. Some regular users of antihistamines become resistant to the drowsiness side effect.

Avoid alcohol and hypnotics when taking antihistamines. The drowsiness from the antihistamines can be deepened by taking the other drug.

Note that antihistamines can also reduce the symptoms of a cold or flu.

## Skin Treatments

People tend to forget that the largest organ of the human body is skin. This shallow coating over the whole body serves many functions. It

protects the body against injuries by cushioning blows with a thin layer of fat. It senses temperature and touch. It regulates body temperature by sweat and changing the size of blood vessels near its surface. Sweat also cleans the body of waste chemicals and regulates the concentration of salt in the body.

Skin does a fair amount of chemistry. To remove waste products, it concentrates the waste into little drops of sweat and pushes this liquid to the surface. The process takes a lot of energy because waste products, like all chemicals, tend to stay dilute until work is applied to concentrate them.

Two different types of pores are used in the skin. One type specializes in oil while the other specializes in water. Since oil and water do not dissolve in each other, it only makes sense for the body to treat them differently.

Skin also makes vitamin D when exposed to sunlight. Like plants, humans can die when not exposed to sunlight — assuming that those people in the dark do not get vitamin D from their food.

Many types of chemicals are placed on the skin to clean, remove blemishes, soothe, and heal. Soothing substances can be applied to irritated skin or mucous membranes. These soothing materials protect the areas where they are applied. Also, they reduce the urge to scratch those areas.

Emollients are fatty or oily substances that, when applied to skin or mucous membranes, protect against air and air-borne irritants. A thin layer of oil keeps the irritants out. At the same time, the skin under the oily layer is made softer as the oil penetrates into the skin and makes the skin more pliable. Some common emollients include petrolatum, rose water ointment (found in cold cream), and hydrous wool fat. Hydrous wool fat is also called "lanolin" and is a mixture of fatty esters.

Astringents reduce the loss of blood from minor cuts and slow other secretions from the skin. These chemicals usually go directly on the areas where the liquid is coming from. Astringents are the chemicals that make antiperspirants work. Some common astringents are salts of metals such as aluminum and zinc, tannins such as tannic acid, alcohols such as ethyl alcohol (grain alcohol), and phenols.

Astringents work by precipitating proteins out of blood or sweat. Proteins dissolved in water or oil react with the medicine to fall out of solution as a solid. This process of falling out of solution is called "precipitation" — just like rain falling down. The visible results are drier

skin. Most astringents only affect liquids on the surface and do not penetrate the skin.

### Acne

Acne is a problem for many teenagers and some adults. Fortunately, there are several treatments for it.

The best cure for acne would be to avoid it altogether. One way to try to avoid it is using only cosmetics that are "hypoallergenic." ("Hypo" means "under" or "less." "Allergenic" means "causes allergies.") This type of cosmetic is less likely than most to cause skin irritation. Also, water-based makeup does not cause an oily buildup that can clog pores and cause acne. Clean hair worn off the face with a minimum of gels, creams, and sprays also slows the clogging of pores.

The link between food and acne is unclear. The iodine in seafood causes problems for some people while other people break out in acne after eating chocolate. Also, some people get acne after eating acid fruits such as oranges.

To clean the clogged pores that cause pimples, acne sufferers should wash twice daily with a mild, non-irritating soap. Products using astringents to dry the skin (such as Stri-Dex Pads or Clearasil) can speed the healing of blemishes.

As the ads say, benzoyl peroxide is the strongest acne medicine you can buy without a doctor's prescription. It is so strong that some users have had to stop using it because of skin irritation. Benzoyl peroxide oxidizes the outer layer of the skin which then peels off. Since most pimples are in the outer layer of the skin, the skin soon looks better. Within six to eight weeks, the results should be clear.

Antibiotics are sometimes applied to the skin to fight bacteria that can cause acne. These solutions go directly on the skin.

Retinoic acid can reduce acne, repair sun-damaged skin, decrease the number of wrinkles, and even treat some types of skin cancer. However, the early users of this wonder drug found that it had a nasty side effect. Prolonged use of the creams would result in skin problems including flaking of skin and burning sensations. For this reason, many of the early patients have stopped using the product.

Some chemists at Hoffmann-La Roche have found that adding a second chemical reduces the unwanted side effects of retinoic acid without harming its useful effects. Those people who have had trouble with this

drug before may have better luck with the new treatment. In case you are curious, the new additive is called "alpha-tocopherol" or "vitamin E" for short.

## Cancer Scares

As pointed out earlier, the risk of food additives causing cancer is smaller than the risk of the food itself causing cancer. But if you watch a lot of TV, you might think that artificial chemicals cause all cancer. The major media are worth pretty much what you pay for them — at least concerning science.

As this book goes to press, there is no way of knowing what the next scare will be. However, it is worth reflecting on a scare that is no longer covered by the newspapers. A man named Paul Brodeur invented the idea that electromagnetic fields from power lines and appliances cause cancer and other diseases. The press was quick to jump on the story. However, the evidence for this claim was very weak. When the topic grew dull and most people decided that the story was probably exaggerated, the papers stopped writing about it.

Almost every day, news people cover stories like that. From Alar to dioxin to cellular telephones, many inventions get this sort of hit-and-run treatment. It helps to be skeptical of scare stories.

# Chapter 6

# Cars and Chemicals

Cars have some of the most useful and exciting chemistry known to humans. Imagine thousands of little explosions causing tremendous heat and whirling hundreds of parts faster than the eye can see. Fluids rarely seen in nature protect and lubricate these parts. Large vehicles often go at speeds that birds would find hard to maintain.

If this sounds more interesting than a chemistry class, you were born too late. At some point in the distant past (the 1940s), you might have heard a lecture or two about the chemistry of engines in a science class. Educators since the 1960s have been draining chemistry classes of much of their usefulness. This chapter will introduce a whole new generation to this chemistry.

However, the science of automobiles is quite deep. It would be impossible for a beginning chemistry book like this to cover the subject in all its gory details. Still, you will learn more about this topic than if you sat through ten chemistry courses. It is strange that such a useful topic was dropped.

## Where a Car's Energy Goes

The energy from burning gasoline becomes mechanical, electrical, and heat energy. Ideally, the fuel would be used for mechanical work such as pushing the car up a hill, or electrical work such as playing the radio. Actually, less than 50% of the energy can be used for those purposes. Much of the energy is wasted as heat.

## Energy losses

Only about 13% of the energy in the gasoline pushes a car forward. Much of the energy is lost in the engine. Many engines are only about 37% efficient. Most of the energy in gasoline is wasted as heat or unburned exhaust fumes.

The loss in the engine is largely due to the temperature range. In general, the higher the operating temperature; the greater the efficiency of the engine. Most cars do not have steam engines because those engines work at lower temperatures and are less efficient. Because diesel engines operate at higher temperatures, diesel engines tend to be more efficient.

Besides the temperature effect, some energy is lost in the engine because of friction and pushing viscous (thick and gooey) oil. It takes work to move parts that are scraping against metal or meeting resistance from a viscous oil. This work does not push the car forward but still consumes fuel.

Much of the energy that leaves the engine does propel the car. Only about 2% of the energy from gasoline goes to the accessories such as air-conditioning, rear-window defrost, and power windows.

Around 4% of the energy from fuel is needed to overcome the tires' resistance to rolling. The harder the tires; the smaller the rolling losses. Hard tires also last longer. However, hard tires do not grip the road as well as softer tires. The poor traction can be dangerous in sharp turns or sudden stops. Any tire represents a trade-off between high gas mileage and long life versus good traction.

Almost 3% of the energy is lost to aerodynamic drag. Flat surfaces and sharp edges on the car's body are likely to slow the car down, as will a solid back gate on a pickup truck. That is why all cars are beginning to look alike with the same sleek styling, and trucks are more often using a net for the tailgate. However, fancy curves also make body work more difficult. On newer cars, it is simpler to replace a body panel than to bend it back into shape. (The use of plastics instead of steel also encourages replacement rather than body work. It is easier to work with steel than plastic.)

About 4% of the energy in gasoline is wasted by running the engine when the car is standing still. If this energy could be stored, gas mileage could improve about 30%. Some books advise turning off the engine if forced to stand still for more than a minute. A complete redesign of the engine could also help. However, this is not something that most do-it-

Even though soybean oil makes up only about 18% of the weight of a soybean, it is sometimes worth almost as much as the soybean meal in that bean. While the meal is used mainly as an animal feed, the oil has a large number of uses. Some common uses for the oil include: cooking oils, inks, plastics, adhesives, coatings, antifoam agents, and as a basic chemical feedstock.

## Sugar

Most sugar comes from either sugar beets or sugar cane. Which plant produces the sugar is of minor importance when trading refined sugar. Sugar from both plants is much the same because sugar is refined to make it pure.

The method of refining the raw sugar is crystallization. In this refining process, raw sugar is dissolved in a little water to make a concentrated solution of sugar water. This solution is then cooled. At the lower temperature, the sugar is less soluble, and it slowly falls out of solution as crystals. These crystals are fairly pure sugar with most of the impurities left behind in the juice. After a couple of recrystallizations like this, beet sugar is hard to tell from cane sugar.

## Pork Bellies

Pigs have two bellies with each weighing about 15 pounds. Bellies make up about 12% of the hog. Oddly, pork bellies are rather popular for futures trading. Many speculators go into this market that is known for wide fluctuations (high risk). One advantage of trading in this market is that you can go home and say, "I brought home the bacon!" (There are 38,000 pounds of pork bellies per contract.)

## Commodity Funds — A Way to Somewhat Reduce Risk

There are some problems with commodities trading. It takes a lot of money to play these markets well. Also, a huge amount of study is required to have a chance against other investors. Finally, a lot of time needs to be spent watching the news to avoid losses on real events or rumors. For these reasons, commodity trading tends to be tough on part-time investors.

There is a possible solution for those who want their savings to grow in times of inflation but who are employed full-time. It is a strategy

that is widely accepted in the stock and bond markets. Namely, mutual funds are available that trade commodity contracts.

Mutual funds allow for the safety of diversification. Perhaps newly found copper in Peru may send copper prices down. However, a mutual fund may still make money if OPEC starts another oil embargo. The higher prices of crude oil may more than cancel out the losses in copper futures. Most small investors have too little time and money to play several markets at the same time.

By investing in mutual funds rather than directly in contracts, the big decisions remaining are when to invest and in what funds to put money. The timing is the same as was discussed at the beginning of the chapter. High inflation is a good time to be in commodity funds. In periods of low inflation, these funds often do poorly.

Most commodity funds are closed-end. This means that they collect the investors' money before beginning to trade and do not let new investors into the fund after trading begins. Many funds can invest in a variety of areas from pork bellies to gold. Others limit the types of investments. Check the prospectus of the fund for all the details.

## Warning: Investing Is Not Foolproof

When a system is generally regarded as foolproof, it has not been tested with a determined fool. Logically, your money should be in cash markets such as stocks and bonds when inflation is under control, and tangible markets such as gold and collectibles when inflation is rising. However, your results depend largely on how you handle each situation and on outright luck.

## Warning: Only Invest What You Can Lose

An old rule among financial planners is to invest only what you can lose. The idea is a good one. It would be foolish to invest heavily in a speculation if a bad harvest or bank swindle could cause you to lose your entire savings. The futures market is particularly risky even for experts. Do not invest money that is needed for things such as food, a college education, or chemistry books.

## Goal Setting

Before doing anything that takes a lot of time or money, you must plan out what you want from that project and from life. Those who plan ahead usually end up with what they aim for. E. J. Corey has demonstrated that in chemistry if you pick a target and then work backward to where you are now, you can make almost anything. It seems as if it is always the simple ideas that get Nobel Prizes.

# Chapter 9

# Learning about Chemicals

If you have read chapters one through eight, you now know more than you did before about chemistry. However, do not kid yourself into thinking that you know it all. Ph.D.'s in chemistry spend ten years to learn a small fraction of the subject. This chapter contains a few suggestions on how to learn more about chemistry.

## The Best Way to Learn: Mentors

Since the dawn of time, the best way to learn about a subject has been to get someone to explain it. Typically, the most successful education has been from a friend, a parent, or an admired teacher. One-on-one teaching is sometimes needed to suggest new ways of solving problems or to point out difficulties. Whether computers can do this is yet to be seen.

## Preparing for Chemistry Lab

A part of learning chemistry is doing laboratory experiments. The dangerous ones are probably best done in high school or college chemistry labs. For most people, cooking is safer and uses many of the skills needed in a lab. In a kitchen as in a lab, following directions exactly under time pressure is important.

### Chemistry sets

For people who are serious about learning chemistry, a time-tested way to learn the subject is the chemistry set. Like many chemists, I had a chemistry set when I was young.

A good chemistry set has equipment such as test tubes, pipettes, and perhaps a scale for weighing. Also, the sets contain little bottles filled with pure samples of various chemicals. A good set might include 20 chemicals and give instructions for dozens of experiments. Many of these experiments involve color changes or solids producing gases. They can be fun to watch.

These sets are most effective when the person doing the experiments is interested in what happens and why it happens. Parents should try to explain what is happening to their children (if the parents know).

It is important to read and follow the directions carefully. While these sets are not as dangerous as some other household chemicals such as drain cleaners, they can be misused to the point of causing injury.

### The chemical notebook

A good way of learning new chemicals is writing them down in a chemical notebook. For those people with computers, entering the chemicals into a software program may make it easier to store and retrieve information. Some simple chemicals to start with would be sugar, table salt, water, air, and gasoline. As more information on a chemical is found, the data files on that chemical can be updated.

## Classes

In my opinion, high school and college chemistry courses spend too much time on advanced concepts such as atoms and molecules. I would prefer them to spend more time on practical chemistry that most people need on a daily basis. Still, if you want to be a doctor, engineer, or scientist, high school and college chemistry are required.

Chemistry is one of the tougher subjects for most people. It requires more time than most classes. You may want to take a lighter course load than usual when taking a chemistry class. At the college level, it may require a full two hours of study out of class for every hour in class.

If you need to take the class, do not worry too much about it. Certainly, do not put it off until the last year because you are afraid of it. While it takes some time and effort, most people pass it like any other course.

## Scientific Literacy

Scientific literacy assumes that everybody must know a core set of ideas about science to be a good citizen. It focuses on the type of news found in newspapers. For example, a student of this topic might follow a story about a spill of sodium hydroxide. He or she would know that it is a caustic chemical used in drain cleaners. The person would know that the chemical can eat through organic materials if given time. A star pupil would know that an acid can be used to neutralize it into a salt and water. This person could follow the story to see how the clean-up went.

Books on this topic contain a lot of good science. Also, the lessons taught are reinforced by the news media. One book of this sort that I truly enjoyed is called *Trashing the Planet* by Dixy Lee Ray with Lou Guzzo. However, these books are not a substitute for classroom chemistry, nor do they teach consumers how to make wise decisions.

## Required Reading for Chemists

Of the two dozen or so books and magazines used to research this book, none has been more valuable than *Chemistry in the Marketplace* by Ben Selinger. It is best used as a reference work. Whenever you have a question on a practical matter, just look up the topic in the book's index. Be warned, however, that it assumes a good understanding of first-year college chemistry and organic chemistry.

## Science Programs

An important way that I learned science in my early years was by watching science programs such as *Nova*, *Connections*, and *Cosmos*. Programs like these are no substitute for talking to mentors or reading. Still, they provide motivation and alert watchers to new areas of study. PBS has been producing shows like these for many years. Some cable channels are also beginning to produce science programs.

## A Vacation Idea

Science museums are truly national treasures. When there are a lot of hands-on exhibits, a few hours in the place can teach both children and adults much interesting science.

# Appendix A

## Answers to Dimensional Analysis Problems

### Problem 1.1

**Cost per ounce of the discounted pastry**

$$\frac{\$\ 1.56}{24 \text{ oz}} = \$0.065 \text{ per ounce}$$

**Cost of the full-price pastry per ounce**

$$\frac{\$\ 3.49}{1 \text{ pound}} \times \frac{1 \text{ pound}}{16 \text{ oz}} = \$0.218 \text{ per ounce}$$

**Which is more expensive?**

The full-priced pastry costs over three times as much per ounce. I would like to assure the reader that the discounted pastries were delicious.

### Problem 1.2

$$5 \text{ minutes wait} \times \frac{1 \text{ hour}}{60 \text{ minutes}} \times \frac{\$\ 15}{1 \text{ hour}} = \$1.25$$

As you can see, the wait was a significant cost. However, it is not clear that all of the digits in the answer above are significant. Few people time their wait so precisely that five minutes are exactly 5.00 minutes. Also, the charge assigned to the time is a little arbitrary. It is probably not exactly $15 per hour. For these reasons, the answer should probably be rounded to one dollar for each five minutes of waiting time.

## Problem 1.3

### Cost of using the highway

$$10 \text{ miles x } \frac{\$0.25}{1 \text{ mile}} = \$2.50$$

### Cost of using the short cut

$$7 \text{ miles x } \frac{\$0.25}{1 \text{ mile}} = \$1.75$$

The saving is $2.50 minus $1.75. This is 75 cents. Of course, this is only one way to get to the answer.

### Time while using the highway

$$10 \text{ miles x } \frac{1 \text{ hour}}{65 \text{ miles}} = 0.15 \text{ hours}$$

### Time while using the short cut

$$7 \text{ miles x } \frac{1 \text{ hour}}{45 \text{ miles}} = 0.16 \text{ hours}$$

The difference in time is less than a minute. It is best to ignore such a small quantity. It would take too much time to calculate the time savings.

## Problem from Chapter 2

$$\frac{1 \text{ can}}{100 \text{ lbs}} \times \frac{45 \text{ mg of caffeine}}{1 \text{ can}} = 0.45 \text{ mg per lb}$$

Because this is below 0.7 mg per pound of body weight, the child may or may not have a tolerance for caffeine. If the child can drink two cans of Coke and still can go to sleep, he or she probably has a tolerance for caffeine.

# Appendix B

## Chemical Glossary and Index

While the main text can be read from beginning to end, this book can also serve as a reference. First, enroll in a high school or college chemistry course. When a new chemical or concept is introduced, find the definition here and look at the page numbers cited. Many of these page numbers will lead to one or more uses for the concept. The examples in this book should help clear up some problems that many students have with the subject.

**1-Methylnaphthalene** - An awful fuel in diesel engines that has a cetane rating of 0. Page 124.

**Abrasive** - A gritty material that can rub off a surface. Sandpaper and toothpaste are two products that use abrasives. Pages 64 and 168.

**Absorb** - To move from a surface into a body. For example, oxygen gas can be absorbed from the atmosphere into a body of water such as a lake (something that most fish appreciate). Also, sponges absorb water. Pages 40, 55, 59, 82, 86, 90, 103-104, 125-126, 140-141, 146, 157, and 174-175.

**Absorption** - 1. The movement of something from a surface into a body as, for example, the absorption of water by a sponge. 2. The movement of food from the stomach or intestines into the rest of the body. Pages 80 and 82.

**Acetylsalicylic acid** - The generic name for aspirin. Aspirin can relieve some types of pain, reduce fevers in adults, and reduce painful swelling. Page 103.

**Acid** - A sour-tasting chemical. Most acids will react with bases (such as sodium hydroxide) to form a salt. Some examples of acids are citric acid (found in oranges), sulfuric acid (found in car batteries), and lysergic acid (found in a fungus). Pages 32, 45, 50, 60, 62, 65, 73, 78-80, 83-84, 86, 93-94, 97, 103, 114-115, 131-133, 146, 148, 150, 155-157, 167, 176, and 189.

**Acidic** - Water solutions with a pH less than 7. Thus, an acidity of pH 1 commonly found in the human stomach would be very acidic. Tap water with a pH of 5 would be less acidic than stomach juices. Pages 65, 94, 103, and 155.

**Acidic salt** - A salt that dissolves in distilled water to make an acidic solution. Page 155.

**Acidity** - How sour a watery solution tastes. For chemists who are too cautious to taste an unknown liquid, pH paper or a pH meter can test the acidity with great precision. Acid solutions have a pH less than 7 while basic solutions have a pH greater than 7. Pages 146 and 156.

**Additive** - A chemical added to something else. Normally, it helps to improve the product in some way (such as extending the product's shelf life) but is not the primary reason why someone buys the product. Pages 55, 85, 92-93, 116, 125-127, 130, and 180.

**Adenosine 5'-diphosphate (ADP)** - A chemical used in the human body's quick energy system. Page 45.

**Adenosine 5'-triphosphate (ATP)** - A chemical that is used by the human body to provide energy for muscle movements. Pages 44-46.

**Adhesive** - A material that can glue two surfaces together. Page 183.

**Aerobic** - In the presence of oxygen. Pages 46 and 48-49.

**Aflatoxin** - An impurity in some foods caused by a fungus. Page 92.

**Air** - The invisible gas common near the Earth's surface. It is about 78% nitrogen gas and about 21% oxygen gas. It also has traces of other gases such as argon, carbon dioxide, and water vapor. Pages 8-9, 13, 15, 18, 48, 52-53, 56-57, 75, 84-85, 90, 95-96, 114, 118-121, 125-126, 128, 131-135, 139-143, 150, 152, 157, 175, 180, and 188.

**Alar** - A chemical that helps keep apples on trees longer to promote better tasting fruit. A scare campaign was successful in stopping its use. Page 116.

**Alcohol** - 1. The active ingredient in drinks such as beer and gin (also known as ethanol). 2. Other related chemicals such as glycerol and methanol. Pages 35-36, 40, 56, 64, 69, 78, 88-91, 104-107, 113-114, 125-126, 142, 146, and 179.

**Aldrin** - An insecticide that is no longer used in the U.S. Page 151.

**Algin** - An additive to ice cream that helps keep it smooth and creamy. Page 70.

**Alkali metals** - The metals: lithium, sodium, potassium, rubidium, cesium, and francium. These all react with water to form a base and hydrogen gas. The heat from the reaction with water often causes the hydrogen gas to react violently with oxygen in the air. Page 5.

**Alkylation** - 1. A type of chemical reaction done on gasoline to raise its octane number. 2. Certain reactions where a chemical is changed into a greasier chemical. One example of the second definition is the conversion of benzene into toluene. That reaction is handy because toluene is less toxic than benzene but can be used in place of benzene for many purposes. Page 125.

**Allergen** - A chemical that causes an allergy. Pages 113, 115, and 148.

**Allergic reactions** - The swelling, sneezing, and other symptoms of the body's reaction to foreign materials. Pages 56-57, 86, 90, 92, 112-113, and 148.

**Allergies** - A person's sensitivities to foreign materials. Many people are allergic to poison ivy and pollen. Some people are allergic to certain foods, dust, or cats. Exposure to these materials can cause great discomfort in allergy sufferers. Pages 56-57, 86, 90, 92, 112-113, 115, and 148.

**Allotrope** - One form of an element. Diamond and graphite are two allotropes of carbon. Phosphorus has three major allotropes — white, black, and red. Red phosphorus is used in match heads. Black phosphorus does not catch on fire as easily as red phosphorus does. White phosphorus gives off lots of smoke when exposed to the air and is used to create smoke screens. All three allotropes will melt to give the same liquid. Page 166.

**Alloy** - A solid mixture of two or more metals. Stainless steels are alloys of iron, chromium, and nickel. Bronze is a mixture of copper alloyed with tin. Pages 50, 164, 169-172, and 180.

**Alpha-tocopherol** - Another name for "vitamin E." This vitamin is sometimes used as an antioxidant to help preserve fats. Page 116.

**Alum** - An aluminum salt that is used in many industries and can stop bleeding from small wounds as well. Page 154.

**Aluminum** - A metal that is lightweight and fairly strong. Pages 16-17, 50, 94-95, 114, 140, 149, 154, and 180.

**Aluminum oxide** - A chemical found in ores such as bauxite and corundum. It is the source of aluminum metal and is also used in ceramics. Page 94.

**Amino acids** - Biological chemicals best known for combining with each other to form proteins. Pages 32, 80, and 148.

**Amitriptyline** - The generic name for one type of antidepressant. Page 102.

**Ammonia** - A gas that smells like urine. When dissolved in water, it is used as a cleaning solution. Pages 105, 147, 149, and 156.

**Ammonium** - The first part of the name of many chemicals. This partial name shows that the chemical contains some nitrogen. The names of many fertilizers begin like this. Pages 104 and 150.

**Ammonium nitrate** - A crystalline solid that is used as a fertilizer and as an explosive. Page 104.

**Amphoteric** - Having some properties of both an acid and a base. These materials react with both strong acids and strong bases. One common amphoteric material is aluminum metal that will dissolve in both strong acids (such as hydrochloric acid) and strong bases (such as sodium hydroxide). Pages 62 and 94.

**Amylases** - Enzymes that will decompose starches. These chemicals are used by the body to digest foods such as bread or potatoes. Page 148.

**Anaerobic** - Without oxygen. Anaerobic bacteria do not need oxygen from the air to live. Muscles in an anaerobic workout do not burn much oxygen. Pages 45-46, 105, and 152.

**Analytical** - Employing methods to divide something into pieces and then identify how the pieces work. An analytical person likes to divide a problem into a number of subproblems and then work on the easier subproblems. This analytical technique has a better track record than trying to solve a difficult problem with simplistic solutions. An analytical chemist can take a complex mixture and divide it into pure chemicals. The chemist can then determine the nature of each of the chemicals. Page 66.

**Anionic** - Negatively charged particles. For example, the chloride part of sodium chloride (table salt) is negatively charged and is therefore anionic. Pages 62, 145, and 148.

**Antibiotics** - Chemicals that can kill germs to help fight infections. Pages 25, 83, 112, and 115.

**Antibodies** - Chemicals produced by the immune system that fight foreign materials in the body. Pages 109 and 113.

**Antidote** - Something that can reverse the effects of a toxin. Page 30.

**Antifoam agents** - Chemicals that will prevent bubbles from forming on top of a liquid. Page 183.

**Antifreeze** - A chemical added to the cooling system of car engines to keep coolant from freezing in cold weather. Ethylene glycol is the most common antifreeze. Pages 130-131.

**Antihistamines** - Chemicals that block the body's response to foreign materials. Pages 35, 57, 90, and 113.

**Antioxidant** - A chemical that slows down reactions between something and an oxidizer such as oxygen. Antioxidants such as Vitamin C can help preserve food. Pages 84-85 and 97.

**Antiperspirant** - A chemical applied to skin to reduce sweating in that area. Hopefully, most of the readers of this definition already use one. If you do not use an antiperspirant, you will find that using one can improve your social life. Page 114.

**Antiseptic** - Something that kills germs on contact. Pages 36 and 104-105.

**Aqua regia** - A mixture of nitric acid and hydrochloric acid that can dissolve gold. Page 167.

**Aqueous solutions** - Mixtures of other chemicals with water that are so thoroughly mixed that not even a microscope can see regions of pure chemicals. Page 36.

**Archimedes** - The best Greek philosopher and one of the best mathematicians of all time. Page 121.

**Artificial** - Made by humans. Pages 2-3, 59-60, 66-67, 70, and 116.

**Aspartame** - The generic name for Nutra-Sweet. Page 69.

**Asphalt -** The residue from refining petroleum. This oily, black gunk is sometimes mixed with other cheap materials and spread over roads as pavement. Page 125.

**Aspirin -** A widely available drug that can reduce fever, swelling, and some types of pain. Pages 25, 103, and 106.

**Astringent -** Something that reduces bleeding. Pages 36 and 114-115.

**Atmosphere -** 1. The gases around something — such as the oxygen and nitrogen around Earth. 2. A unit of pressure equal to the weight of the atmosphere at sea level. Pages 56 and 98.

**Atom -** The smallest bit of an element that retains many of the element's properties. As you can (or maybe cannot) imagine, atoms are very, very small. Helium is an example of a material that is made of many single atoms. Oxygen gas is an element made of molecules of two atoms of oxygen combined. Most chemicals are complex combinations of many atoms. Pages 15 and 188.

**ATP-phosphocreatine system, the -** The chemical system in the human body that brings energy quickly to the muscles. Page 46.

**Avoirdupois -** The weights used in the British system. Some avoirdupois weights are the ounce, the pound, the stone, and the hundredweight. Pages 169-170.

**Bacteria -** One type of germ. Some can cause diseases. Antibiotics are very effective against bacteria. Pages 58, 78, 96, 99, 104-106, 112, 115, 150, 152, and 155.

**Bakelite -** An early plastic that made Leo Baekeland very rich. Page 112.

**Baking soda -** A white crystalline salt best known for absorbing odors and producing carbon dioxide gas when heated. Carbon dioxide from baking soda can puff up bread. Page 74.

**Barbiturates -** One type of drug that can promote sleep. Barbiturates are less popular now than they were in the past. Pages 35-36 and 106.

**Base -** A chemical that can raise the pH of water above 7 — making the solution basic. These bases can react with acids to form salts. A common base is sodium hydroxide (also called concentrated lye). Sodium hydroxide can help clean clogged drains. Pages 62, 94, 103, 146, 150, 155, and 157.

**Base metal -** A metal that will tarnish or rust when exposed to air, moisture, and heat. Pages 171 and 180.

**Basic** - 1. Something that must be learned before more advanced topics can be learned. 2. A material that can raise the pH of water by reacting with acids. Pages 1, 4, 38-39, 51, 65-66, 77, 83, 94, 103, 150, 155, 176, and 183.

**Battery** - A device that changes chemical reactions into electricity. Pages 120, 128, 131-133, and 142.

**Bauxite** - A type of rock rich in hydrated aluminum oxides that is used as an ore to make aluminum metal. Pages 16-17 and 180.

**B-complex vitamins** - A group of water-soluble vitamins needed for good health. Page 82.

**Benzene** - A solvent useful for dissolving organic chemicals. It is used less often than in the past because it has been found to cause cancer. Page 125.

**Benzoyl peroxide** - An oxidizing agent. Among other uses, it can bleach foods such as flour. Page 115.

**BHA** - A food additive that helps protect some foods from oxygen. Page 97.

**BHT** - A food additive that helps protect some foods from oxygen. Page 97.

**Biochemical** - Having to do with the chemistry of living things. Page 38.

**Biochemistry** - The study of the chemical processes of life. Page 25.

**Biotin** - A B-vitamin needed for good health. Pages 82-83.

**Bleach** - 1. To make whiter. 2. A chemical that makes things whiter. Many oxidizers will bleach clothing and other materials. Pages 62, 140, 147, and 149.

**Blend** - 1. To mix. 2. A mixture. Pages 65, 121, and 124-125.

**Blood sugar** - A sugar found in the blood called "glucose" that helps to supply the body with energy. Pages 45 and 78.

**Body tissue** - The solid to semisolid parts of a body. Pages 26, 81, and 87.

**Boil** - To heat a liquid until it begins to evaporate quickly. Pages 54-55, 73-75, 89, 125, 130-131, 143, 150, 153-154, and 178-179.

**Boiling point** - A temperature that depends on the liquid and the surrounding pressure. A liquid begins to boil at its boiling point. In a place such as New York City that is close to sea level, water boils at around 212 degrees Fahrenheit. At the same pressure, ethyl alcohol boils at 173

degrees Fahrenheit. Because Denver, Colorado, is roughly a mile above sea level, its atmospheric pressure is only about 83% that of New York City. Since there is less pressure pushing on the water, the boiling point of water in Denver is close to 203 degrees Fahrenheit. Pages 75, 125, 130-131, 154, and 179.

**Borax** - A white powder with a variety of uses including the control of cockroaches. Page 151.

**Boron** - 1. A mineral needed by plants in trace amounts. 2. An element found in compounds such as borax. Page 150.

**Brass** - A metal that is an alloy of copper and zinc. Pages 164, 172, and 176.

**Brine** - A solution of salt and water. Page 52.

**British thermal unit** (b.t.u.) - A unit of energy invented by the British but only U.S. engineers still use it. A horse working steadily at one horsepower for one hour can produce about 2,550 b.t.u.s worth of work. Pages 18-19.

**Brittle** - A property of a material that makes it more likely to break than to bend. Page 93.

**Bromine** - When found in its pure form, a noxious brown liquid that gives off toxic fumes. It is more commonly found as part of other chemicals. These chemicals are numerous and have a wide variety of properties. Page 37.

**Bronze** - A metal that is an alloy of copper and tin. Page 172.

**Brucine** - A very bitter, toxic chemical sometimes used to denature (poison) alcohol. Page 91.

**Buffer** - 1. A device that polishes something by rubbing. 2. A combination of an acid and a salt, or a base and a salt that can make it difficult to change the pH of a solution. Pages 146, 155, and 176-177.

**Buffered solution** - A solution that requires the addition of a large amount of acid or base to significantly change the solution's pH. A buffered solution stays in a narrow range of pH when small amounts of acid or base are added. Pages 146 and 155.

**Buffering salt** - A salt used in combination with an acid or base to stabilize the pH of a solution. Page 155.

**Builders** - Chemicals added to a detergent to help the surfactant work better. In the past, phosphates were widely used for this purpose. Pages 146 and 149.

**Buoyancy** - The upward push on an object immersed in a fluid. For example, the upward push on someone in water can bring a diver to the surface without any effort from the diver. The upward push from air on a hot-air balloon can push it off the ground. Page 52.

**Burn** - To react with oxygen or another oxidizer at high temperature. For example, lighting a match to a chemistry book will cause it to burn. Best results are achieved if you first open the book so that the oxygen can easily reach the burning pages. Pages 13, 32, 45, 48-50, 54, 56-58, 74, 80, 97, 108, 117-120, 122, 126, 129, 132, 134, 138, 143, and 178.

**Butane** - A gas at room temperature and pressure that can be easily compressed into a liquid. It is flammable and, so, can be used as a fuel. Pages 56, 125, and 179.

**By-products** - Something produced in addition to the main product. For example, coal gas was once widely used for heating and lighting. This gas was made by heating a type of coal. This process also produced a lot of coal tar as a by-product. William Perkin changed this material that was once considered just waste into a valuable by-product by showing that coal tar could be converted into dyes. Pages 41 and 182.

**Caffeine** - The active ingredient of coffee and some alertness pills. Pages 35-37, 40, 42, 97-98, 152, and 193.

**Calcium** - 1. A flammable metal that reacts with water. 2. A cationic chemical found in hard water. Pages 80-82, 86, 93, 111, 150, and 174.

**Calcium channel blockers** - A class of drugs used to treat hypertension (high blood pressure) and certain heart problems. Page 111.

**Calcium ions** - A chemical found in some aqueous solutions. It helps to make hard water what it is. The human body uses this chemical to help muscles move. Page 111.

**Calcium stearate** - A fatty acid salt with many uses including wax crayons and lubrication. Page 93.

**Calorie** - 1. When used to mean a food calorie, about 1,000-3,000 of these energy units are needed daily to keep an adult at a constant weight. 2. When chemists are talking about chemical energy, they are talking about an energy unit exactly 1,000 times smaller than a food calorie. Therefore,

about 1,000,000 to 3,000,000 of these tiny chemical calories are needed daily by adults. Pages 5, 18-19, 55, 69, 78, 80-81, 96, 121, and 123.

**Carbohydrates** - Chemicals such as sugar, starch, glycogen, and cellulose. Pages 33, 44-45, 49-50, 69-70, 72, 77-78, 80, 82-83, 86-87, and 89.

**Carbon** - An element that can be found in its pure form as graphite or diamond. Most known chemicals contain some carbon. The study of chemicals containing carbon is called organic chemistry. Pages 125, 134, 136, 140, 142, 152, 166, and 168.

**Carbon dioxide** - A gas that is heavier than oxygen or nitrogen. Carbon dioxide is normally given off by combustion and by living things when they burn food. Pages 19, 45, 48-49, 74, 97-98, 119, 142, 150, and 155.

**Carbon fiber** - Long, brittle strands of carbon. Carbon fibers can add strength to some composites. These composites are made stiffer and stronger than the plastic without the carbon fibers. Page 140.

**Carbon monoxide** - This is a gas often formed as a by-product of combustion. It is quite poisonous because it can stop the transport of oxygen inside a human body. Pages 49, 122, 134, and 142.

**Carboxylic acid** - One type of organic acid. Many chemicals fall into this category, including: fruit acids, vinegar, aspirin, and the fatty acids that form fats. Only used in glossary.

**Carrageenan** - An additive to ice cream that helps keep it smooth and creamy. Page 70.

**Casein** - A mixture of proteins found in milk and cheeses. Page 153.

**Castor oil** - An oil extracted from castor oil plants. It is sometimes used as a lubricant. Page 60.

**Catalyst** - A chemical used to speed up chemical reactions. The human body uses many types of enzymes as catalysts. These enzymes can speed up reactions such as the breakdown of starch into sugar. These reactions are millions of times faster in the presence of the catalyst. Modern automobiles also use catalysts to destroy pollutants in the exhaust. Pages 45 and 171-172.

**Catalytic converter** - A device on modern cars that removes some forms of pollution from the exhaust. Pages 134 and 171.

**Cationic** - A chemical with a positive electrical charge. An easy way to associate the word "cationic" with a positive charge is to see the letters "cat" in the front of word and think of a furry little kitten. The kitten is

associated with positive emotions. Chemists have to use memory techniques like this to learn much of the chemical jargon. Pages 62 and 148.

**Caustic** - A base that can corrode organic materials. An example of a caustic chemical is sodium hydroxide that is the active ingredient in many drain openers. Page 189.

**Cell** - The smallest unit of a living creature. Animals, plants, and humans are composed of billions of tiny cells. Microorganisms are often just a single cell. Cells in a living thing are born, live, reproduce, and then die. Cells are surrounded by a thin membrane. In plants, the cell membrane is usually protected by a cell wall. Most advanced cells also have tiny organelles such as mitochondria that specialize in one task such as producing energy. Pages 45-46, 49, 62, 72, 79, 81, and 111-112.

**Cellulases** - Enzymes that will digest cellulose. The human gut is not rich in such enzymes, and for that reason, cannot digest fiber in food. Page 148.

**Cellulose** - A fibrous material from plants that is actually a type of carbohydrate. Cows can digest it but not humans. Cotton is mostly cellulose. Pages 70-73 and 148.

**Cement** - A substance that starts off soft and then hardens to bind things together. Page 50.

**Central nervous system stimulant** - Such "uppers" as speed or caffeine. "Central nervous system" is a long-winded way to say "the brain and spinal cord." Page 36.

**Ceramic** - Inorganic materials such as clay that are used to make pottery — among other things. Page 140.

**Cetane** - A type of diesel fuel that rarely causes a diesel engine to knock. Cetane is given a cetane rating of 100. Pages 124-125.

**Cetane number** - A number that measures how often a diesel fuel will knock in a diesel engine. A fuel with a cetane rating of 0 will knock quite often while a fuel with a rating of 99 will rarely knock. Pages 124-125.

**Charcoal** - Impure carbon made by heating dead plant and animal material with no oxygen around. Charcoal has a large surface that can trap odors and colored organic chemicals. Page 122.

**Charge** - 1. A quantity of some chemical. 2. An electrical potential held by an object. A charge on a person can result in a shock when touching a

doorknob. When chemicals possess a charge, they tend to be more reactive than chemicals without a charge. Pages 62, 133, 145, and 148.

**Charged** - Something that has either a positive or negative electrical charge. Charged objects will often shock someone who touches them. Salts break into tiny charged particles. However, salt solutions will not shock someone who touches them because the positive and negative charges cancel out. Of course, if you put a live wire in a salt solution and then touch it, it will shock you. Pages 62, 132-133, and 142.

**Chemical** - 1. Anything that can be tasted, smelled, touched, lifted, or that occupies space is either a pure chemical or a mixture of chemicals. 2. Something related to the study of matter and its transformations. Pages 1-3, 11, 18-19, 23, 25, 30, 32-33, 36, 38-39, 40-41, 44-46, 51-52, 54, 57, 59-67, 69-71, 76-86, 89, 91-92, 94, 96-97, 99, 102-109, 111-117, 119-120, 122-123, 125-126, 131-132, 136-137, 142-143, 145-147, 149-151, 153-154, 156-159, 171, 173-175, 179, 181-183, and 187-189.

**Chemical bonds** - Those forces that hold compounds together. Page 63.

**Chemical energy** - Energy produced when converting chemicals into new chemicals. For example, a good deal of chemical energy is stored in a gallon of gasoline. By heating the gasoline around a source of oxygen, a great deal of heat and some light is given off. This is chemical energy changing into heat and light energy. Pages 44, 120, and 123.

**Chemical plant** - A building or a group of buildings where matter is changed to produce materials of greater value. Page 182.

**Chemical processes** - The way chemicals change into different chemicals. Page 182.

**Chemical property** - How a chemical interacts with different chemicals. For example, one chemical property of an acid is that it will react with a base. Page 36.

**Chemical reaction** - Change in the nature of one or more chemicals (usually with an accompanying change in energy). The burning of gasoline and the rusting of iron are two examples of chemical reactions. Pages 23, 33, 41, 45, 80, 89, 94, 104, 119, 125-126, 150, 171, and 175.

**Chemical structure** - The way a chemical looks at its smallest level. For example, water looks like two Ping Pong balls sticking out of a baseball. DNA looks like a spiral staircase. Chemists just love talking about this subject because many of them work in this area. The topic is a little too

advanced for this book — meaning it takes considerable effort to learn while providing few benefits for the reader. Page 67.

**Chemically altered** - Something that has been changed by chemicals. For example, morphine directly out of a poppy is fairly potent. Codeine, which is found in some cough medicines, is morphine that has been chemically altered to make it less addictive. Of course, codeine will still cause false positives on drug tests. Page 112.

**Chemist** - Someone paid to know something about chemistry. Pages 1, 3, 12-13, 17, 19, 23, 26, 32, 51-53, 63, 65, 67, 71-72, 74, 83, 86, 94, 103, 105-107, 109, 115, 122, 126, 135, 149, 151, 156, 176, 182, 187, and 189.

**Chemistry** - The study of matter — the stuff that makes things what they are. Pages 1-2, 15, 23, 25-26, 38, 43, 51, 61, 64-65, 69, 72, 78, 81, 83-84, 90, 92, 98, 101, 103, 114, 117, 131, 135-136, 145, 154, 156-157, 159, 163, 166, 178, 184-185, and 187-189.

**Chemistry set** - A toy that lets the user pretend that he or she is a chemist. Pages 187-188.

**Chloral hydrate** - A material that can interact with alcohol to cause a person to pass out. Page 35.

**Chloramines** - Gases rich in nitrogen and chlorine sometimes formed by mixing bleach with ammonia. These gases are very irritating if inhaled. Pages 149 and 155.

**Chlordane** - One type of insecticide. Page 151.

**Chlorine** - This element is a toxic, greenish gas that can oxidize fuels just as oxygen can. It is used in some swimming pools to oxidize germs to death. Pages 54, 147, 150, and 154-158.

**Chlorogenic acid** - A chemical found in many plants. Page 84.

**Cholesterol** - A natural material made by animals and humans that (like a fat) is more soluble in oils than in water. The human body can change it into various steroids. Pages 2, 34, 79, 87, 109-110, and 175.

**Chromatography** - A method of separating chemicals that have different solubility properties. For example, chromatography can easily separate an oily material from a salt by dissolving both in water and then running the solution over a tar. The oil goes into the tar while the salt stays in the water. Pages 66-67, **68**, and 174.

**Chromium** - 1. A hard, shiny metal. 2. A cationic chemical found in a few salts. Pages 81 and 168.

**Citric acid** - An acid found in citrus fruits and other foods that gives the food a tart flavor. Page 60.

**Clarity** - A measure of how clear something is. A gem with a high clarity would let light shine through it. Page 166.

**Clay** - Mud — especially mud that can be shaped when wet but becomes hard after baking. Page 146.

**Clog** - To prevent liquid or air from passing through a pore. Strongly basic solutions are sometimes used to remove clogs from plumbing. Pages 79, 115, 126-128, 134, 136, and 154.

**Coal** - Deposits of decayed vegetable matter found in the earth. It is solid and mostly made of carbon. Pages 70 and 122.

**Coal tar** - A dark, gooey liquid made by heating coal. Page 70.

**Coat** - A thin layer. Most painters will apply several coats of a light-colored paint to cover up a dark paint. Pages 62, 74, 93-94, 103, 113, 140, 151, 164, 168, 170, 174-175, 179, and 183.

**Coating** - A thin layer on the outside of something. Pages 17, 49, 94, 113, 135-136, 170, 179, and 183.

**Cobalt** - 1. One of the metallic elements. 2. A mineral needed in trace amounts by plants. Pages 150, 164, and 168.

**Cod liver oil** - A liquid made by extracting chemicals from fish livers. Pages 98 and 101.

**Coke** - A solid residue left after heating coal. Coke is mostly carbon. This should not be confused with the nickname for a popular cola drink. Page 122.

**Colligative properties** - Properties of a solution that depend on how much solute is dissolved in the liquid solvent rather than what the solute is. For example, dissolving one teaspoon of sugar into water will cause the solution to freeze at a lower temperature than pure water. Likewise, one teaspoon of salt will also lower the freezing point (but not to exactly the same temperature as the teaspoon of sugar). This drop in the freezing point of water depends on how much stuff is dumped into the solution. Adding a second teaspoon of sugar will lower the freezing point even more. Osmosis also depends on how much solute is dissolved on either side of a semipermeable membrane, and not what is dissolved. Page 131.

**Colored** - Having color. A good diamond is not colored while a ruby is a colored gemstone. (Rubies have a red color.) Pages 70, 141, 147, 165, and 167-168.

**Combustible** - Something that can be burned. Page 108.

**Combustion** - A chemical reaction that gives off light and heat. The most common example of combustion is a fire burning. Chemists often use this term to mean the reaction of a material with oxygen to produce carbon dioxide and water (along with some by-products). Pages 56, 119, 125, 128, 136, and 138.

**Commodity** - A product that is roughly the same regardless of the source. Crude oil is a type of commodity. While each lot is slightly different, crude oil from the Middle East is rich in hydrocarbons in the same way that crude oil from Texas is rich in hydrocarbons. Many commodities are traded in markets and are often the subject of speculation. Pages 88, 160, 177-178, 181, and 183-184.

**Complex carbohydrates** - Materials such as starch and cellulose that can be decomposed into simple sugars. Pages 50, 78, and 86.

**Complex chemicals** - Chemicals that are hard for a chemist to learn and remember. Pages 2 and 70.

**Complex mixtures** - Mixtures with three or more different chemicals. Complex mixtures are time-consuming to purify. Pages 17, 86, and 125.

**Composite** - A solid mixture with distinct parts. For example, concrete reinforced with steel bars is a composite material. Fiberglass with strands of glass in plastic is also a composite. Page 140.

**Composition** - What something is made of. Pages 88 and 145.

**Composting** - The practice of piling organic waste and letting germs feed on it. Page 152.

**Compounds** - Chemicals made up of more than one element. Pages 60, 63, 98, and 157.

**Compress** - To squeeze or push together. A liquid or solid will not change its volume when it is compressed. However, a gas will take up less volume under pressure. Thus, a person can compress a balloon filled with air down a size or two, but not a rock. Pages 120, 135, and 154.

**Compressor** - A device that pushes down on something — usually a gas. Pages 153-154.

**Concentrate** - A solution with most of the liquid part (the solvent) removed. It is often cheaper to ship a concentrate than to ship a larger volume with the solvent still in. Most orange juices are first concentrated and then diluted later. Pages 114 and 131.

**Concentrated** - A lot of a chemical squeezed into a small volume. For example, a bottle of vodka has more alcohol than a six-pack of most beers. This means that alcohol is concentrated in the bottle of vodka. Pages 53, 89, 131, 146, 149, and 183.

**Concentration** - A measure of how much of a chemical is packed into a solution. The concentration of alcohol in vodka is around 40% or so. In every five ounces of vodka, there is roughly two ounces of pure alcohol. Pages 37, 46, 53, 111, 114, 131-132, and 156.

**Condense** - To put what before took up a large volume into a smaller volume. Gases fill a large volume with little mass. By condensing the gas into a liquid, the same mass goes into a smaller volume. Pages 54, 89, 127, 130, 143, and 179.

**Condition** - How something is. A room with lots of dirt and clutter is in a disordered condition. A child who regrets having made the mess is in a sorry condition. A painting where the colors have faded is in poor condition. A coin right off the presses is in mint condition. Pages 41, 61, 69, 134, 162-165, and 177.

**Conduct** - To allow something such as heat or electricity to pass through. Metals tend to conduct these things well. Pages 94, 136-137, 145, 166, 169, and 179-180.

**Conductor** - A material that lets heat or electricity flow through it. Pages 170, 172, and 179.

**Contract** - To become smaller. For example, when you cool a metal, the metal will contract. Pages 44-45, 51, 89, 111, and 175.

**Coolant** - A fluid that takes heat from one place and dumps the heat elsewhere. A common example of a coolant is the mixture of water and ethylene glycol found in most automobile cooling systems. This coolant takes heat from the engine and dumps it into the car's radiator. Pages 130-131.

**Copper** - A reddish metal often used to make wires. Pages 81, 89, 150, 169-172, 176, 179-180, and 184.

**Corey, E. J.** - A chemist who helped to develop the logic of organic synthesis. Page 185.

**Corrode** - To slowly gnaw away at something. Pages 132, 140, 167, and 180.

**Corrosive** - Something that eats away on something else. For example, a corrosive acid can eat away on a metal until the metal dissolves. Pages 5, 52, 149, and 155.

**Cosmetics** - Materials applied to the skin to improve a person's appearance. Some examples of cosmetics are lipstick, cold cream, and blush. Pages 59-60 and 115.

**Coumaric acid** - An acid found in some plants. Page 84.

**Cracking** - A group of processes done at an oil refinery to maximize the value of each barrel of crude oil. The most common cracking process is changing high-boiling heating oil or diesel fuel into gasoline. Another cracking process adds unsaturation to oils to produce the starting materials for plastics. Page 125.

**Cream** - A smooth mixture of oils and water. Because the oils in milk are less dense than water, cream that is rich in these oils will float on milk. Pages 60, 70, 76-77, 81, 99, and 114-115.

**Crud** - A very technical term for a dirty buildup. Pages 135-136.

**Crude oil** - Oil pumped out of the ground before it is refined into products such as gasoline. Pages 55-56, 122, 125, 178-179, and 184.

**Crystallization** - Purifying a solid by dissolving it in a liquid and then letting crystals of the pure solid fall out of solution. Various drugs are made pure by crystallization. This process is also used to make rock candy out of sugar. Page 183.

**Crystallize** - To become a crystal. Normally, the crystals come from either a liquid or a solution. In a rather pretty bit of chemistry, someone watching the liquid can see the crystals grow as they crystallize out of solution. This process is more than just beautiful; it is also useful. These crystals are usually far more pure than the original solution. For this reason, crystallization is a good way to purify a chemical. Page 70.

**Crystals** - A relatively pure form of a chemical that is notable for having sharp points. Two of the best-known chemicals that form crystals are water and carbon. The crystalline form of water is snow. Crystals of carbon are known as diamonds. Pages 36-37, 70, 103, 131-133, 153, and 183.

**Cubic centimeter (cc)** - A centimeter is roughly half an inch. A cubic centimeter is the volume of a little cube with sides of one centimeter. If water were placed in that cube, it would weigh one gram (about 1/28th of an ounce). Another term for a cubic centimeter is a milliliter. Pages 52 and 102.

**Cyanuric acid** - A herbicide and pool chemical. Therefore, it would be stupid to plant radishes next to your swimming pool. Page 157.

**Cycle** - A pattern of actions that repeat. For example, in some places, it gets hot in the summer, cools down in the winter, and warms up again the next summer. This is a cycle of temperatures. Another example would be becoming alert in the morning upon awakening, becoming tired after lunch, being wide awake around 5 PM and then becoming tired after 9 PM. That is a sleep and alertness cycle. Cycles are very common, all the way from radio and sound waves to fashions. Pages 8, **27**, 28-30, 38-39, 120, 148, and 175.

**DDT** - An insecticide that has been used widely since 1939. While the United States and some other countries have banned it for dubious reasons, many other countries still use it. It is the chemical most responsible for the drop in the number of malaria cases. Page 151.

**De Hevesy, George** - A chemist known for his work using radioactive materials. Page 12.

**Decaffeinated** - A mixture with most of the caffeine removed. Pages 97-98.

**Decompose** - To fall apart. Many chemicals will decompose when they are heated to a high temperature. Outwardly, the chemical may look as if it turns black upon heating. If the chemical has decomposed, the original chemical is gone, and it may be very difficult to change the chemical back to what it was before. Pages 105, 151, and 157.

**Degreaser** - A chemical that removes oils and greasy materials. Page 137.

**Dehumidifier** - A device that takes water out of the air. Page 143.

**Deice** - To remove ice. ("De" means to get rid of while "ice" is the thing that goes.) Page 137.

**Demoisturant** - A chemical that removes moisture (water). Pages 136-137.

**Denatured alcohol** - Alcohol that has been made undrinkable by adding a poison. Page 91.

**Denser** - The same volume contains more mass. For example, a gallon of blood weighs about 8.7 pounds while a gallon of water weighs 8 pounds. Therefore, blood is denser than water. Pages 18, 51-52, 133, and 178.

**Density** - How heavy a volume of something is. Hot air is usually a little gas in a lot of space so its density is low. Pure mercury is a very dense liquid. A little bottle of mercury is surprisingly heavy. Liquid water is the standard for measuring density. Water has the density of 1 gram per cc in the metric system. Water has the density of 1 pound per pint in the United States Engineering System. A density lower than 1 is less dense than water. A density higher than 1 is more dense than water. Octane, a type of gasoline, has a density of 0.7. Mercury has a density of 13.5. Pages 52, 121, 127, 133, 135, 143, 166, and 178.

**Deposit** - A residue left behind. Pages 62, 127-128, and 130.

**Depressant** - A drug that makes the user less perky. Page 90.

**Detector** - A device that senses the presence of something. A smoke detector tests the air for smoke and sounds an alarm if some is found. Other detectors can sense light, radiation, or lies. Pages **68** and 172.

**Detergent** - A type of chemical that helps different chemicals dissolve in each other. Pages 105, 126-127, 130, 135, 145-149, 154, and 168.

**Detoxahol** - A drug that shows promise of one day sobering people who have had too much to drink. It has not been approved for human use. Page 107.

**Dextrin** - A material made by partially decomposing starch with heat or acid in water. It is used in everything from pills to fireworks. Page 73.

**Diamond** - A gem made of pure carbon. Pages 165-168.

**Diastase** - A mixture of enzymes from malt can quickly change starch into sugars. Page 88.

**Dichlorvos** - A type of insecticide. Page 151.

**Dieldrin** - An insecticide related to aldrin. Like aldrin, dieldrin is no longer made or used in the United States. Page 151.

**Diesel engine** - An engine that burns diesel fuel. Diesel fuel is slower to burn than gasoline and requires more heat to ignite. Because a diesel engine works at higher temperatures, it gets better miles per gallon. Pages 118, 124, 134-135, and 141-142.

**Diesel fuel** - The material that is burned in a diesel engine to provide energy. It is a liquid similar to gasoline but slower to evaporate. Pages 124-125 and 141.

**Diffusion** - A natural flow of chemicals from areas of high concentration to areas of low concentration. Without any work from the outside, a solution will gradually become the same concentration throughout — even if it starts off by dumping concentrated brine into pure water. Likewise, gases will form homogeneous mixtures if given time. Pages 48-49.

**Digestive enzymes** - Chemicals in the gut that help break down food into usable materials. Page 34.

**Digestive juices** - A mixture of acid and enzymes that changes food into chemicals that the body can use. Page 103.

**Dilute** - A solution with a little solute in a lot of solvent. An example of a dilute solution would be putting one teaspoon of salt in a gallon of water. An even more dilute solution would be putting one teaspoon of salt in a lake. Pages 53, 105, 114, 130, and 149.

**Diluted** - Made less pure. For example, gin is rather concentrated alcohol. Gin is more drinkable when it is diluted with soda water. Page 90.

**Dimensional analysis** - A powerful branch of mathematics neglected by most mathematicians. It focuses on the units of numbers and permits numbers to be converted to different units. For example, it lets people convert time in minutes into time in seconds. Pages 6, 10, 19-20, 24, 42, 72, and 191.

**Dioxin** - A toxic chemical also known as TCDD. Despite an enormous amount of bad press, it is not clear that this chemical has killed anyone. However, it is still to be avoided if possible because it can cause a severe rash. Page 116.

**Dipeptide** - A simple protein made of two amino acids. Page 69.

**Dirt** - A highly technical term for crud or soil. Pages 11, 17, 53, 62, 126-128, 130-131, 135-136, 145, 147, and 154.

**Discolored** - Changed to a new color. If a white shirt becomes gray, the shirt has been discolored. Page 164.

**Disordered** - Not in an ordered pattern. A bed that has not been made yet is an example of a disordered bed. Chemists use this term to mean order at a very small level. They say that crystals with their flat edges and sharp points are highly ordered. Liquids are less ordered because they tend to

slosh around. Gases are very disordered because they tend to fly apart. Page 153.

**Displace** - To remove something while putting something in its place. For any chess fans who might be reading this, a capture is made by removing the opponent's piece and putting your own piece where the opponent's piece was. The opponent's piece was displaced by your own piece. When you step into a bathtub, you displace the water where your foot is, and the water moves out of the way. Page 121.

**Displacement** - Replacing something with something else. Displacement is part of the reason why a hot-air balloon rises. As the balloon fills, it displaces heavier air outside the balloon with the lighter air of the balloon. That is, as the balloon expands, the outside of the balloon invades where the air around the balloon used to be. The displaced air pushes on the balloon to help it rise in the air. Page 121.

**Dissolve** - To mix until a solution is formed. Pages 35-36, 52, 56, 59, 66, 73, 79, 86, 94, 98, 101, 103-104, 111, 114, 125-127, 131-132, 135-137, 145-146, 148-149, 155-157, 167, 176, and 182-183.

**Distillate** - The liquid produced when vapors from a distillation are condensed. Page 89.

**Distillation** - Heating a liquid until it turns into a vapor followed condensing the vapors back into a liquid. The reason for distilling a mixture in this manner is that the condensed vapors are normally richer in chemicals that can be easily vaporized. Pages **54**, 55, 89, 125, and 178.

**Distillation tower** - A huge tower at an oil refinery that separates crude oil into fractions. These towers are sometimes seen in movies with a flame coming from the top. I once was turned down for a job with an oil company because I asked the recruiter a question about those flames. I did not know why this company wasted some of the flammable gases in crude oil in this way. She gave me the answer that it relieves pressure in the tower and that it shows that the process is working normally. In an interview, stick to praising the recruiter, avoid technical topics, and *never* suggest a new idea. Page 125.

**Distilled spirits** - A liquid produced by distillation — normally an ethyl alcohol solution. Page 90.

**Distilled water** - Water that is purer than tap water because it has been condensed from steam. It is also somewhat purer than rain water (which

was also condensed from water vapor) because rain water is exposed to more air pollution. Pages 111 and 130-131.

**Distilling -** A process that helps purify liquids. It involves evaporating a liquid and then condensing the resulting vapors. It is commonly used to purify hard liquor. Mother Nature uses this process to purify rain water. Pages **54** and 55.

**Disulfiram -** A nasty chemical that can make drinking alcohol less pleasant. Eating a little of this followed by drinking a little alcohol will cause nausea. This chemical's more respectable uses include being a fungicide or a chemical to harden rubber. Page 107.

**Diuretic -** A chemical that makes you go pee. Page 111.

**Dosage -** A measure of how much medicine is given at one time. For example, a typical dosage of aspirin to treat a headache is 300 to 600 mg (milligrams) — one to two tablets. Pages 103 and 106.

**Drug -** A chemical that has an effect on the workings of a living thing. Some common drugs are coffee, beer, tobacco, aspirin, and heroin. Pages 25, 35-36, 63, 79, 92, 102-103, 106-107, 111-113, 115-116, and 168.

**Drug interactions -** Drugs working together in ways unlike any single drug. For example, some alcohol might make you sleepy, as would a cold medicine. However, if both are taken at the same time, they might interact to produce a coma. Page 106.

**Dry -** 1. Not wet. 2. Free of water. This second definition is what a mechanic means when he or she says that some gasoline is dry. It still feels wet, but it is free of water that might cause problems in the gas tank. (The word has another five meanings such as a dry wine lacking sweetness. If you are curious, most dictionaries include this word.) Pages 9, 16, 36, 61, 77, 96-97, 115, 136-137, and 156.

**Dry ice -** The solid form of carbon dioxide that can provide many hours of amusement. It vanishes in a huge puff of white gas. Also, it freezes things quickly — including fingers unless you are careful. Pages 36 and 97.

**Drying additives -** Additives that soak up water. Page 127.

**Ductility -** The ability to be drawn into a wire. Copper needs to have ductility to be made into electrical wires. Pages 169-170.

**Dust -** A fine powder. Page 128.

**Dye -** A colored material that can stick to something else. Pages 15, 17, 62, 70, and 112.

**Dyeing** - Changing the color of a material using a dye. Page 11.

**Ecological** - Related to where and how plants and animals live. Page 152.

**Efficiency** - A ratio of useful output to what was inputted. For example, an engine that is 100% efficient converts into mechanical work all of the energy put into it. Most engines have efficiencies between 98% and 2%. A good gasoline engine might have an efficiency of 35%. Pages 17 and 118.

**Elbow grease** - Hard physical labor. (Slang around the Carpenter household.) Page 153.

**Electric car** - A car powered by an electric motor. Pages 119 and 141-143.

**Electrical energy** - Electricity in a form that can do work. Page 131.

**Electrical potential** - A difference in the amount of electrical charge between two locations. The most common unit for this is the volt. Page 26.

**Electricity** - The power that comes out of an electric socket. Pages 17, 131-133, 136-137, 145, 157, 166, 169-170, 172, and 179-180.

**Electrochemical** - Related to the changing of electricity into chemical reactions or vice versa. The most obvious example of this is how a battery produces power. The chemical reactions inside the battery are harnessed to produce electricity. Less obvious is the conversion of iron into rust. This rusting process also involves a flow of electricity near the site of the rusting. That is why the posts of a battery rust faster than the surrounding metal. Page 132.

**Electrodes** - The ends of a wire that can carry an electrical current. Pages 26, 28, 132, and 166.

**Electrolysis** - Using electricity to decompose chemicals. A car battery uses electrolysis to store energy. The alternator feeds in electrical energy to decompose crystals of lead sulfate. Industry also uses electrolysis sometimes. One industrial process is the electrolysis of water to form oxygen gas and hydrogen gas. This requires great care as this mixture of gases is *very* explosive. Page 157.

**Electrolyte** - A solution that will conduct electricity. Salt solutions are the most common type of electrolyte. The liquid part of a battery is also an electrolyte. Page 177.

**Electromagnet** - A magnet that requires electricity to work. Page 16.

**Electromagnetic radiation** - Radiation with no mass that can travel through a vacuum. The most famous type of electromagnetic radiation is common, everyday light that helps humans see. Other types include infrared radiation, ultraviolet (UV) radiation, radio waves, microwaves, and X rays. Page 173.

**Electron** - A tiny particle (much smaller than an atom) that has a tiny negative charge. A flow of electrons is called an electrical current, and this flow powers all electrical devices. Pages 174 and 176.

**Electronic ignition** - The use of electricity to create sparks. Page 18.

**Electroplated** - Coated with a layer by running an electric current though a solution. Normally, the electroplated layer is good at protecting the metal beneath it. Gold is a favorite metal for this because it never tarnishes. Page 171.

**Electroplaters** - Those people who can electroplate a new surface onto an object. Page 177.

**Elemental sulfur** - A yellow, crystalline solid that can kill insects. Pages 150-151.

**Elements** - The 110 or so chemicals that act as building blocks to construct the other 3,000,000 or so chemicals. Of these elements, carbon is the most important. Pages 53, 81, 83, and 166.

**Emerald** - A type of green stone. Page 167.

**Emission** - Something that is sent out. For example, emissions from clouds include rain, snow, and lightning. Emissions from cars include water, carbon dioxide, and pollution. Pages 96, 128, and 134.

**Emit** - Give forth. While “secrete” implies to give off a liquid, “emit” usually implies a sound or radiation. Pages 110, 142, 146-147, and 151.

**Emollients** - Materials applied to skin to smooth or soften it. Page 114.

**Emulsion** - A mixture that to an unaided eye looks like a solution. However, when an emulsion is studied with a microscope, an observer can see little regions of pure solvent and pure solute. Detergents are used to make stable emulsions. Page 60.

**Endothermic** - A change that takes in heat energy and makes the surrounding temperature go down. Ice melting is an endothermic reaction. Ice takes in heat and can make the temperature around it drop. Certain chemical reactions are also endothermic and can take in heat. Page 104.

**Energy** - Ability to do work. There are many forms of energy including heat, mechanical, electrical, etc. Pages 4, 8-9, 15, 17-18, 25-26, 43-46, 48, 52, 54-55, 58, 73, 75, 78, 80-81, 85-87, 95-97, 110, 114, 117-123, 128-133, 136, 138-139, 141, 143, 172-173, 175, and 180.

**Energy-efficient** - Converts most of the energy into useful work. Page 17.

**Entropy** - A measure of how disordered something is. A high-entropy room will have clothes everywhere and boxes of Chinese carry-out lying around. A low-entropy room will have everything in its proper place. As you can tell, it requires work to reduce the entropy of an area. Page 48.

**Environment** - Those things that surround the area of interest. Most "green" people are primarily interested in civilization and therefore, use the term to mean areas that are untamed. Pages 3, 17, 47, 142, 153, and 175.

**Enzymes** - Chemicals used by the body to speed reactions. Most enzymes are made of proteins. Pages 33-34, 57-58, 62, 73, 80, 82, 88, 99, and 147-148.

**Equilibrium** - A situation where small changes provoke equal and opposite reactions to restore the original situation. The most common chemical example of this concept is using ice cubes to cool a drink. As long as the ice cubes are in the cup, the drink will stay cold. Warming the cup with your hands will just cause the ice to melt faster. The equilibrium ceases when the ice cubes have melted. Pages 47-48, 51, and 156.

**Ester** - The product of a carboxylic acid reacting with an alcohol. Some important esters are fats, aspirin, vitamin C, and wintergreen oil. Pages 78-79 and 114.

**Estrogen** - A chemical that promotes reproduction in females. The most potent human estrogen is a hormone called "estradiol." Page 82.

**Etch** - To eat away at something with a corrosive chemical. Page 167.

**Ethyl alcohol** - The active ingredient of beer, wine, and hard liquor. It is also called "grain alcohol" or simply "alcohol." Pages 89-91, 104, 114, and 126.

**Ethylene** - A flammable gas produced at an oil refinery. It is mostly used for welding or to make other chemicals. Page 179.

**Ethylene glycol** - A polyalcohol often used as an antifreeze in cooling systems. Page 130.

**Evaporation** - Changing a liquid into a vapor. If you study a puddle of water for several hours, you will find that it slowly evaporates until it

disappears. The water changes into water vapor. Many other liquids can evaporate in this manner. Some other liquids that evaporate include butane, gasoline, alcohol, and Freon. Those liquids are called "volatile" because they quickly evaporate. Other liquids are slower to evaporate and, thus, are less volatile. Pages 16 and 60.

**Exhaust** - The mixture of gases leaving an internal-combustion engine. This is the stuff that comes out the car's tailpipe. Pages 118, 120, 133-134, and 178.

**Exothermic** - A change that gives off heat. Most of the well-known chemical reactions are exothermic. For example, combustion is a process where a fuel is reacted with oxygen to produce water, carbon dioxide, and heat. The heat around a fire can be intense. It can even be used to roast marshmallows. Page 104.

**Expansion** - Increase in size. Get bigger. Pages 51, 137, and 175.

**Experiment** - A little test to see how something will react. Pages 12-13, 65, 69, and 187-188.

**Explosion** - A violent outburst. For example, lighting a stick of dynamite can cause chemical reactions that release a lot of heat and trigger an explosion. Pages 117, 120-121, 123, and 135.

**Exponential decay** - A concept from mathematics that is very useful in several sciences. With exponential decay, the amount of something that changes form is proportional to how much is present. For example, a ton of uranium will change into other chemicals at a rate that is twice as fast as a half ton would. Something that displays this behavior is inherently self-destructive, and changes form at random but with a predictable half-life that is sort of an average lifetime. Some materials decay within seconds while others take many years. Page 29.

**Extract** - 1. To separate from a mixture with the use of solvents. 2. The material that was purified by an extraction. Pages 60 and 97-99.

**Extracted** - Separated and purified from a mixture, usually with the help of a solvent. For example, coffee is rich in caffeine but pure caffeine is sometimes more valuable than coffee. To extract the caffeine from the coffee, a solvent such as trichlorethane (an oily liquid that is a little denser than water) is added to the coffee. It dissolves the caffeine and other oily parts of the coffee. The trichlorethane solution is drained away from the coffee. The trichlorethane is evaporated and a solid rich in caffeine is left behind. The raw caffeine is purified and put into soft drinks. Much of the

caffeine in soft drinks was extracted from coffee beans. Pages 36 and 97-98.

**Extraction -** Removing something from inside something else. Chemists use this term when removing oily materials from a mixture using an oily solvent, or when they remove salts from a mixture by using an aqueous (watery) solution. A consumer is likely to encounter this term when talking with a chemist about caffeine extraction or when talking with a dentist about a tooth extraction. Page 97-98 and 182.

**Faded -** Grown dim. For example, colors that have lost their original intensity have faded. Page 164.

**Fahrenheit -** A common measuring system for temperature in the United States. The freezing point of water is around 32 degrees in this system, and the boiling point is around 212 degrees. The bigger the number; the hotter it is. Pages 18, 51, 60, 95, 98, 131, 137, 143, and 168.

**Fat -** A basic nutrient that is rich in food energy. Pages 12, 34, 44-46, 48, 65, 74, 77-80, 82-84, 86, 88, 93-94, 101, 103, 107-108, 114, 123, and 148.

**Fat-soluble -** A chemical (such as an oil) that can dissolve in fat. Normally, fat-soluble chemicals stay in the body longer than water-soluble chemicals. Pages 83 and 101.

**Fatty -** Related to fat. Pages 12, 78-79, 93-94, 103, and 114.

**Fatty acids -** The oil-loving part of fats. Fatty acids combine with glycerol to form fats. Pages 78-79 and 93-94.

**Fatty ester -** A fat. It is called an "ester" because esters are the products of carboxylic acids reacting with alcohols. Other important esters (besides fats) are aspirin, vitamin C, and wintergreen oil. Pages 79 and 114.

**Feedstock -** The raw materials for a chemical plant. If the plant is making sugar, it will need either sugarcane or sugar beets as feedstock. Page 183.

**Fermentation -** Germs such as yeast feeding on carbohydrates to produce carbon dioxide and ethyl alcohol. Page 89.

**Ferromagnetic -** Able to become a permanent magnet such as iron can. Pages 94 and 164.

**Fertilizer -** A material that helps plant life to grow. Pages 146 and 150.

**Fiber -** 1. The part of food that the human body cannot digest. 2. A long and thin object such as a string. Pages 46, 71, 78, 86-87, 140, and 148.

**Filler** - Material added to increase the bulk of a product. These fillers can range in importance from fillers to keep detergents free flowing to solders to join metals together. Figuratively, people apply this term to mean information that is time-consuming and of little value. Page 146.

**Film** - A thin layer of material. Pages 55, 62, 74, 94, and 168.

**Filter** - A device to separate those things that go into it. Some filters separate solids from liquids. Other filters separate sounds or colors or data. Most chemists use filters to remove solids from a mixture. Pages 52, 89, 128, 130, 154, and 175.

**Fire** - A chemical reaction that has a fuel and an oxidizer such as oxygen. It is widely known for giving off heat. Pages 3, 15, 18, 53, 55-57, 74, 90, 104, 108, 119, 132, 137, 156, and 176.

**First law of thermodynamics** - The energy of a system is equal to the sum of the energies that went into it. For example, let's consider a balloon to be a system. The balloon starts with a heat content that depends on the temperature. Suppose you push against the balloon and thereby do work on the balloon. That work is added to the original heat in the balloon, and the temperature inside the balloon goes up slightly. This first law lets chemists and engineers keep track of where energy goes. Pages 75 and 119.

**Flame** - Part of a fire where the fuel is reacting with the oxidizer to produce heat. Pages 18, 56, 74, 119, and 156.

**Flammable** - Something that can be burned. Sometimes the label will include the helpful adverb "EXTREMELY." This should alert the reader not to smoke around the chemical. Some things are less flammable (such as chemistry books), and so less care is required. Pages 56, 125, 137, and 156.

**Flavor** - A chemical recognized by the human nose and tongue. Pages 2-3, 12, 15, 65-67, 69-71, 77, 88-91, and 94.

**Fluid** - A gas or a liquid that flows to fill the shape of a container. Pages 53, 81, 102, 111, 117, 128-129, 131-133, 149, and 153.

**Fluorescence** - The property of some materials of absorbing light of one color and emitting light at a different color. This can help to make yellow clothes look whiter. Page 172.

**Fluorescer** - A chemical that absorbs radiation of one wavelength and gives off light with a different wavelength. Fluorescers are added to some detergents to make clothes look whiter. Pages 146-147.

**Fluoride** - An anionic chemical that is added to water to help strengthen teeth and to kill germs. Page 81.

**Foam** - A mass made of many bubbles. Pages 64, 93, and 147.

**Folate** - A salt of the vitamin called folic acid. Pages 82-83.

**Folic acid** - One of the vitamins needed in humans. Page 73.

**Formaldehyde** - A toxic gas used to make some plastics. Solutions of formaldehyde can be used to help preserve dead people. Page 91.

**Formulating** - Making a recipe. Page 149.

**Formulation** - 1. A mixture that comes from a recipe. 2. The process of creating a recipe. Page 62.

**Fortnight** - Two weeks. A favorite unit for reference books. For example, 147,840 furlongs per fortnight is 55 miles per hour. Pages 19 and 170.

**Fraction** - A part of a mixture with a narrow boiling range. For example, gasoline is a fraction of crude oil with a boiling point of around 150-400 degrees Fahrenheit while kerosene is another fraction of crude oil with a boiling point of between 350-600 degrees Fahrenheit. Crude oil itself is a very complex mixture of many hundreds of chemicals. The above fractions are less complex. Pages 125 and 179.

**Fragrant** - Has a nice odor. Page 61.

**Freeze** - To make motionless. While water flows easily to the touch, frozen water is hard and puts up more resistance. When the temperature goes down, many materials that are liquids or gases at room temperature will start to freeze into solids. Pages 51, 95, and 131.

**Freezing** - A temperature cold enough to freeze something. Freezing temperature for water is 32 degrees Fahrenheit or 0 degrees Celsius. Pages 51, 70, 94-95, 126-127, and 130-132.

**Freons** - Nontoxic gases with a range of boiling points convenient for refrigeration. Pages 153-154.

**Fresh water** - Water common to many lakes and rivers that is not polluted with salt. Pages 52-53 and 59.

**Fructose** - The sweetest sugar. It is sometimes used to preserve the texture of ice cream. Pages 50 and 69.

**Fruit acids** - Sour-tasting chemicals naturally found in many fruits. Page 60.

**Fuel** - A material that can be burned to create energy. Pages 17, 45, 48, 50, 54-56, 74, 105, 117-128, 133-136, 138-139, 141-142, 154, 156, and 178-179.

**Fuel mixture** - A mixture of fuel and air that can easily be ignited into flame. Pages 120-121, 123, 128, and 133-135.

**Fumes** - Gaseous vapors. Pages 118 and 156.

**Fungicide** - A chemical that kills fungi such as mold or mushrooms. Pages 92 and 150.

**Furlong** - Six hundred and sixty feet — a favorite unit in many reference works. For example, 147,840 furlongs per fortnight is 55 miles per hour. Page 170.

**g/cc** - A unit of density found in many chemistry and medical books. When translated into English, this means "grams (g) per (/) cubic (c) centimeter (c)." A gram is a unit of mass that is about 1/28th of an ounce. A cubic centimeter is a little cube with edges that are about 0.4 inches long. When you put that tiny weight into the tiny box, you have a density of 1 g/cc. Water has a density of 1 g/cc, and so, the numbers are easy to work with. Page 52.

**Gallon** - A unit of volume commonly used in the United States. Pages 42, 55, 88-89, 121, 123, 127, 129, 138-139, and 142.

**Garlic oil** - The oily part of the herb called garlic. Page 151.

**Gas chromatograph** - A device that can separate and help analyze mixtures of gases and mixtures that can be vaporized. Pages 67 and 174.

**Gas chromatography (GC)** - A technique where a sample of chemicals is changed into a mixture of gases and then the gases are analyzed. Gas chromatography can help analyze the production of drugs. It also helps with the blending of perfumes, foods, and gasoline. Pages 67, **68**, and 174.

**Gas phase** - A fluid that will take the shape of its container and will expand or contract if the container does. The most important gas is actually a mixture of gases called air. Page 95.

**Gaseous** - Having no shape and able to expand like a gas. All gases are gaseous. Pages 67, 122, 154, 156, and 174.

**Gold** - One of the metallic elements that is a rather inert. It retains its economic value when other currencies are worthless. Also, it makes beautiful jewelry. Pages 50, 164-172, 177-178, and 184.

**Grain** - 1. The seeds of certain grasses. 2. The weight of a single grain of wheat. Pages 70-72, 86-89, 169, and 181.

**Grain alcohol** - One name for the active ingredient in drinks such as beer and vodka. Another name is ethanol. Most people call it simply "alcohol." Pages 36, 90-91, 114, and 126.

**Gram** - A unit of mass from the metric system that is about 1/28th of an ounce. Pages 52, 55, 72, 79, 109, and 170.

**Graphite** - A black, slippery solid made of pure carbon. Pages 166-168.

**Greenhouse effect** - Where light goes into an area, but the resulting heat is trapped there. In greenhouses, light travels through glass but the glass stops most of the heat leaving the greenhouse. Even on cold days, greenhouses can keep plants warm and bathed in light. Pages 140-141.

**Greenhouse gas** - A gas that lets light through but keeps heat in. Venus is much hotter than Earth partly because of greenhouse gases. Page 142.

**Growth hormone** - A chemical made by the body that is thought to promote the growth of body tissue. Page 30.

**Gunk** - An ugly, gooey mess. Page 122.

**Hard water** - Water rich in calcium, magnesium, and iron impurities. These impurities can cause problems for users of soaps and detergents. Page 146.

**Hardness** - The resistance of a solid to scratching. A hard rock such as a diamond is tough to scratch. Page 166.

**Heat** - This is known as the lowest form of energy because other forms of energy tend to become heat. Pages 8-9, 18, 23, 41, 44, 55-56, 61, 63, 65, 70, 73-76, 89, 93-94, 99, 104, 117-119, 123, 125, 128-131, 133-134, 136-137, 140-141, 143, 149-150, 152-154, 166-167, 170, 175, and 179-180.

**Heat of combustion** - The amount of heat given off by burning something. It can be viewed as the potential chemical energy in a flammable object. The heat of combustion of gasoline helps determine how far a tank of gasoline will push a car. Page 56.

**Heat of fusion** - The amount of heat given off by a gram of water as it freezes. Other liquids also freeze with a characteristic heat of fusion. Pages 55 and 137.

**Heat of vaporization** - The amount of heat needed to change a gram of boiling water into a gram of water vapor. Other liquids also boil with their own heats of vaporization. Page 55.

**Heat pump** - A device that can transfer heat from one area to another. Modern refrigerators use a heat pump to keep food cold. Pages 153-154.

**Heating oil** - A fraction of crude oil that boils at a higher temperature than gasoline or kerosene. As you can guess, it is burned to provide heat for buildings. Page 179.

**Heat-resistant** - Able to withstand high temperatures before burning up. The tiles on the outside of the space shuttle are heat-resistant. Likewise, oven mitts are heat-resistant. Much to the chagrin of NASA, oven mitts were invented before the tiles were. Thus, NASA cannot claim that oven mitts were a spin-off of the space program. Page 168.

**Hemoglobin** - The part of a red blood cell that a) is red, b) contains iron, and c) carries oxygen. Page 81.

**Heptane** - A type of gasoline that often knocks in a gasoline engine. It has an octane rating of 0. Page 124.

**Herbicide** - A chemical that can kill plants. Page 150.

**Hexachlorophene** - An ingredient in germ-killing soaps that kills germs. It can have toxic effects; and so, the FDA regulates it. Page 104.

**High-energy state** - A condition ripe for producing energy. One example of a high-energy state is placing a book on a high shelf. With little effort, someone could knock the book off the shelf, and some sound energy would be created when the book hits the floor. Another example is recharging a dead battery. The battery goes from a low-energy state to a high-energy state. Page 131.

**High-octane** - A term that means a fuel rarely knocks in a gasoline engine. Pages 123-124.

**Hirsutic acid** - An antibiotic made by a fungus. Page 83.

**Histamine** - A chemical in humans that causes most of the symptoms of an allergy. Pages 90 and 113.

**Hormone** - A chemical found in the body that helps to regulate how the body works. Pages 30, 32, and 46.

**Horsepower** - About 2,550 b.t.u.s worth of work per hour. Some horses can produce energy at this rate. The unit is more commonly used to measure power from car and truck engines. The bigger the number; the more powerful the engine. Page 121.

**Humidity** - A measure of how much water vapor is in the air. Pages 41, 63, and 175.

**Hydrocarbons** - Oily chemicals made of hydrogen and carbon. Some common hydrocarbons include: gasoline, diesel fuel, kerosene, propane, butane, methane, and heating oil. Pages 134, 142, and 176.

**Hydrochloric acid** - A mixture of hydrogen chloride gas and water. When a lot of the gas is dissolved in the water, this liquid can cause skin burns. Pages 155, 167, and 176.

**Hydrogen** - 1. An elemental gas that burns very strongly. This was the gas that made the Hindenburg float in the air. 2. Part of many chemicals such as hydrocarbons, water, and some acids. Pages 62, 105, 122, 125, 132, and 157.

**Hydrogen chloride** - A gas that dissolves in water to produce hydrochloric acid. Page 155.

**Hydrogen peroxide** - A strongly oxidizing liquid that turns into oxygen gas and water when exposed to trace impurities. Relatively safe if it is in dilute solutions. A possible explosive if it is in high concentration. Pages 62 and 105.

**Hydrometer** - A device that can find the density of a liquid. Page 133.

**Hydrophilic** - "Hydro" means "water." "Philic" means "loving." Together, the word means "a chemical that would prefer to dissolve in water than in an oil." Page 59.

**Hydrophobic** - "Hydro" means "water." "Phobic" means "afraid." Together, the word means "a chemical that would prefer to dissolve in an oil than in water." Pages 59 and 126.

**Hydrous wool fat** - A fatty material that is mixed with other things to create various ointments. It is better known as lanolin. Page 114.

**Hypnotics** - Chemicals that promote sleep. Pages 35-36, 40, 106, and 113.

**Hypoallergenic** - Less likely to cause allergic reactions. Cosmetics that are hypoallergenic are less likely than most to cause skin problems. Page 115.

**Hypochlorite salts** - A class of bleaches. Pages 147 and 155-158.

**Hypothesis** - A guess based on existing data. For example, suppose you are sitting under a tree when you feel something hit your head. When you look down, you see an apple rolling away from you. At this point, you may form the hypothesis that you are sitting under an apple tree. To test the hypothesis, you may decide to look up and try to see some apples. Pages 11-12.

**Ice** - The solid form of water. Pages 7-8, 18, 50-52, 54-55, 70, 95, 102, 104, 137, 153, and 168.

**Ignite** - To light a fire. Pages 90, 119-120, 123, and 133.

**Ignition** - Starting a fire. Pages 18, 133, and 135.

**Impurities** - Materials that keep a chemical from being pure. For example, salt in sea water is an impurity. If the salt were removed and the germs killed, the water may become pure enough to drink. Pages 54-55, 91, 130, 146, and 183.

**Inert** - Will not react with most chemicals. Gold is considered rather inert because it does not tarnish or react with oxygen. The gas called "helium" is so inert that many chemists believe it will never react with other chemicals to form new compounds. Page 146.

**Inertia** - Tendency for things to keep on doing what they are doing. Some examples would be a log that is hard to start into motion, a train that is hard to stop, and a middle manager who does not want to learn a new job. Pages 44-45.

**Infrared** - A type of radiation that is felt as heat. It is just like light, only of lower energy per photon. Pages 67, 134, and 173-174.

**Ingredients** - What went into a product. Pages 4, 14-16, 59-61, 67, 72-73, 76-77, 86, 88-89, and 91.

**Inhibit** - To either slow down something or prevent it entirely. Page 57.

**Insect repellent** - Something that drives bugs away. Page 152.

**Insecticide** - A chemical that kills insects. Page 150.

**Insoluble** - Something that will not dissolve to form a solution. For example, bowling balls are insoluble in water. Gasoline is also pretty much insoluble in water. Pages 87, 132, 148, and 157.

**Insulation** - Something that stops the flow of heat or electricity. Pages 8 and 18.

**Insulin** - A material that helps the human body use sugar. Pages 33 and 102.

**Interaction** - Something that results from combining two different things. Pages 35 and 106-107.

**Interleukin-1** - One of the chemicals found in the human body that can promote fevers. Page 30.

**Internal-combustion engine** - A device that provides power by burning a fuel inside it. Most cars and trucks use an internal-combustion engine to convert gasoline or diesel fuel into energy. Page 119.

**Invert sugar** - A type of sugar that can be made by reacting table sugar with water around certain acids or enzymes. Honey is mostly invert sugar mixed with pollen. Pages 69 and 92.

**Iodine** - An element that is sometimes applied in an alcohol solution to broken skin to help prevent infection. Pages 54, 81, 105, and 115.

**Ion** - A very, very tiny particle that has a net electrical charge. Salts are among the many chemicals that are made of ions. Pages 111, 145, and 148.

**Ionic** - Something that contains ions. Ionic solutions are better than nonionic solutions at conducting electricity because a flow of ions will carry an electric current. Page 145.

**Iron** - A common metal that can be magnetized. It is combined with other materials to form steel, hemoglobin, and rust. Pages 16, 45, 81-82, 86, 94, 132, 136, 140, 150, 164, and 168.

**Irradiation** - Exposing something to high-energy radiation. Page 96.

**Isomerisation** - A chemical reaction that can increase the octane rating of a gasoline. Page 125.

**Isooctane** - A type of gasoline that rarely knocks in gasoline engines and has an octane number of 100. Page 124.

**Isopropyl alcohol** - A flammable liquid related to ethyl alcohol. Like ethyl alcohol, a little isopropyl alcohol solution on a cut can kill germs. Unlike ethyl alcohol, isopropyl alcohol is toxic if taken internally. Page 104.

**Jet fuel** - A mixture of hydrocarbons that powers jet engines. It boils at a higher temperature than gasoline. Pages 125 and 178.

**Jewel** - A precious stone or a bearing made from a precious stone (sometimes found in watches). Page 165.

**Jeweler's rouge** - A type of fine abrasive used to clean the surfaces of fine jewelry. Page 176.

**Karat** - A measure of how pure gold is. Pure gold is 24-karat while the purity of most jewelry is less than 20-karat. Pages 165 and 169.

**Kerosene** - Hydrocarbons often used for heating purposes that are less volatile than gasoline. Pages 55-56, 176, and 178-179.

**Kilogram** - A mass that is 1,000 times larger than a gram and about 2.2 times larger than a pound. Pages 18, 72, and 109.

**Laboratory experiment** - A test of the sort that is done by scientists in labs. These experiments are usually quite rigorous with every possible outside factor carefully controlled. Chemists have the luxury of using laboratory experiments to settle disputes. Other sciences, such as economics and astronomy, lack this method of proof. As a result, the basis for chemistry is much sounder than many other sciences, and chemists rarely argue about basic theories (with cold fusion being a major exception). Page 187.

**Lacquer** - A varnish applied in a thin coat over an object to protect the object from damage due to oxidation or abrasion (rubbing). Pages 174 and 176-177.

**Lactic acid** - A chemical that makes milk sour as it goes bad. Lactic acid is also produced when muscles work with too little oxygen. Pages 45, 50, and 60.

**Lactose** - Milk sugar. A carbohydrate found in human milk and cow milk. Page 99.

**Lanolin** - A fatty material used to make certain ointments. Page 114.

**Large scale** - While a reaction of a small scale can be conducted in a test tube, a reaction on a large scale might require a bucket or a swimming pool to hold it. Many large-scale reactions in the petroleum industry require reactors much larger than a typical house. Pages 125 and 153-154.

**Latex -** A milky fluid with resins, gums, and waxes mixed in. Page 57.

**Lavoisier, Antoine -** An early chemist known for his careful experimental work and well-reasoned analysis of the results. His work on oxidation has proved to be of great value. Page 13.

**Law of chemistry -** A predictable pattern of events having to do with matter or changes in the form of matter. For example, heating a balloon causes the gas inside the balloon to expand. A chemist can bet a week's pay that it will happen. Some of the more important laws have been given names. The fact that heat expands gases is called Charles's law or the ideal gas law. Page 15.

**Law of conservation of energy -** While energy can change form, such as changing from mechanical energy to heat energy, it does not simply disappear. This rule of thumb is helpful to engineers doing design work. If the energy going in does not equal the energy going out plus the energy increase in the system, the engineer knows that something is wrong. Page 75.

**Law of mass conservation -** Mass can be accounted for by simple addition. For example, a pound of gasoline and a pound of wood equals two pounds of mass. If the pound of wood and the pound of gasoline are burned in a sealed container weighing a total of 10 pounds (including the wood and the gasoline), the weight of the sealed container will still be 10 pounds at the end. However, some of the wood and gasoline will turn into carbon dioxide and water. Pages 15-16.

**Le Chatelier's principle -** Once something is in equilibrium it will react to outside pushes by pushing back and trying to stay in equilibrium. Pages 47 and 51.

**Lead -** 1. A soft metal that can be toxic if consumed. 2. Part of the name of a chemical that contains lead. Many of these chemicals are poisonous as well. Pages 110, 126, 132, and 173.

**Lead sulfate -** The salt formed when lead in a car battery reacts with sulfuric acid to produce electricity. This salt changes back into lead and sulfuric acid when the alternator recharges the battery. Pages 132-133.

**Light -** 1. The type of electromagnetic radiation that helps humans see. 2. Not heavy. Pages 31-32, 40, 44, 50, 58-59, 61, 64, 93, 96, 114, 121, 131, 140, 146-147, 157, 166, 169-170, 173-175, 178, 180, and 188.

**Like dissolves like** - Oils dissolve each other but not water. Water will dissolve many salts, alcohols, and sugars, but not oils. Pages 59, 66, 127, 136, and 146.

**Lime** - 1. A green citrus fruit rich in vitamin C. 2. A caustic chemical rich in calcium. Pages 82 and 130.

**Linoleum** - Linseed oil turned solid after reacting with oxygen. Linoleum is part of a popular floor covering. Page 182.

**Lipases** - Enzymes that will digest fats. Page 148.

**Lipids** - Oil-soluble chemicals found in living creatures. The most famous lipids are fats and cholesterol. Pages 34 and 79.

**Liquefied petroleum gas (LPG)** - A fraction of crude oil rich in propane and butane gases. Page 179.

**Liquid chromatography** - A way to analyze a solution with several solutes. For example, squirting a dilute solution of tree sap into a properly prepared liquid chromatograph will show the chemist how many chemicals are in the sap and provide clues about what those chemicals are. Pages 67 and **68**.

**Liquid phase** - A fluid that will take the shape of its container but will not expand or contract in the way that a gas does. The most important liquid is water. Pages 51 and 131.

**Liter** - A metric unit of volume that is equal to 1,000 cubic centimeters or 1.06 liquid quarts. If a quart and a liter of a liquid both have the same price, choose the liter size. Pages 72 and 121.

**Low-boiling liquid** - A liquid that turns into a gas at close to room temperature or even colder temperatures. Pages 153-154.

**L-tryptophan** - An amino acid found in many proteins. Pages 32-33.

**Lubricant** - A chemical that makes something slippery. Pages 51 and 136.

**Lubricate** - To add a chemical to make something slippery. Pages 61-62, 93, 117, and 138.

**Lubricating oil** - An oily liquid that makes something slippery. It is useful when parts must move against each other because it reduces wear, keeps down heat from friction, and extends the life of the machine. Page 125.

**Lubrication** - To make slippery. Page 119.

**Lye** - A strongly basic solution. A good example of a lye solution is a drain cleaner that has sodium hydroxide as its active ingredient. Pages 150, 155, and 157.

**Magnesium** - 1. A lightweight, flammable metal. 2. A cationic chemical found in hard water. Pages 81 and 150.

**Magnet** - A material that is attracted by metals such as steel. Pages 16, 94, and 164.

**Magnifying glass** - A curved piece of transparent material that bends rays of light to change the apparent size of objects viewed through it. Pages 164 and 166.

**Malathion** - A type of insecticide. Page 151.

**Malic acid** - An acid commonly found in fruits. Page 60.

**Malleable** - Easy to bend. Pages 169 and 177.

**Manganese** - 1. A metallic element. 2. A mineral needed by plants and animals. 3. Part of a longer chemical name of a compound containing some manganese. Pages 150 and 168.

**Mannitol** - A sugar used as a food sweetener and stabilizer. Page 69.

**Mass** - To paraphrase Carl Sagan, how much *stuff* is in an object. For example, a one-pound loaf of bread has one pound of mass. A one-pound lead pipe also has one pound of mass. Pages 4-5, 15-16, 51-52, 78, 81, 102, 127, 135, and 170.

**Mass spectrometry (MS)** - One way to find out what an unknown chemical is. Page 174.

**Material** - A chemical or a mixture of chemicals. Pages 2-3, 5, 12-15, 17, 29-30, 35, 37, 45, 49, 51-52, 59-60, 62, 64, 66, 71, 74, 78-79, 81, 88-89, 92-94, 97-98, 110-114, 122, 127, 131-132, 136-137, 140, 148-149, 152-153, 156, 166-168, 173-175, 178-179, 181, and 189.

**Matter** - Any type of chemical or mixture of chemicals. Pages 2, 15, 89, and 160.

**Mechanical energy** - The ability to push things around. Pages 44, 119-120, 128, 136, and 143.

**Medicine** - 1. The art of healing. 2. A drug. Pages 32, 34, 36, 57, 84-85, 99, 101-102, 106, 109, 111, and 114-115.

**Melamine** - A chemical that, like most bases, forms salts when mixed with acids. It is also an important part of some plastics. Page 157.

**Melanin** - A pigment in the human skin. Pages 58 and 62.

**Melatonin** - One of the hormones found in the brain. Page 32.

**Melt** - To change from a solid into a liquid — normally by using heat. Pages 16-17, 55, 104, 128, 137, 153, and 168.

**Melting point** - The temperature when a solid begins to turn into a liquid. The melting point for ice is 32 degrees Fahrenheit. Page 168.

**Membrane** - A thin sheet. Pages 52, 62, 79, 105, 111, and 114.

**Mercury** - A dense liquid metal. It is often found in thermometers. Page 50.

**Metabolize** - To change a material such as a food into chemicals the body can use. This word means pretty much the same thing as "digest." Page 107.

**Metal** - A material that is shiny and can conduct electricity with little resistance. The most important metal is iron. The strangest metal is mercury that is a liquid at room temperature. Many people's favorite metal is gold. Pages 5, 16, 50, 52, 54, 90, 93-94, 105, 114, 118, 130, 132, 136, 140, 150, 154-155, 159, 164-172, 176-177, and 180.

**Metal corrosion** - An eating away at a metal. This is often the result of a reaction of the metal with oxygen to form metal oxides — although acids will also eat away at metals. The rusting of steel is the most famous example of metal corrosion. Page 52.

**Meter** - 1. A unit of length that is about one yard long. 2. A device to measure something. Pages 72 and 196.

**Methane** - A flammable gas found in natural gas. Page 122.

**Methanol** - An alcohol that can cause blindness if swallowed. It is also called "wood alcohol." Pages 91 and 125-126.

**Metric system, the** - An allegedly easy to learn and easy to use system for measuring the physical world. United States engineers have strongly resisted its adoption in the U.S. If given the chance, many Americans would find it easier than having to remember all of the odd conversions of the British system (1,760 yards in a mile, 1,728 cubic inches in a cubic foot, 4 pecks in a bushel, and so on). Pages 72 and 169-170.

**Micro -** The first part of a word that means either "one millionth" or "very small." An example of the one millionth is a "microliter" which is one millionth of a liter. An example of very small is a "microscope" which is a scope that can see very small things. Pages 14, 19, 27, 35, 95-96, 111, and 173-174.

**Microscope -** A device that can magnify the images of some very small things. Pages 111 and 173-174.

**Microsecond -** One millionth of a second. Page 19.

**Milk sugar -** A sweet material found in milk. It is also called "lactose." Pages 70 and 78.

**Milligram (mg) -** One thousandth of a gram. Because a gram is smaller than an ounce, a milligram is very small. Pages 37, 42, 72, 81, and 102.

**Milliliter -** A volume that is one thousandth of a liter. Because a liter is about a quart, this makes a milliliter roughly 1/30th of an ounce. Page 72.

**Millisecond -** One thousandth of a second. Page 19.

**Mineral -** 1. Occurring naturally in the earth. 2. A pure material of nonliving (inorganic) origin. 3. An inorganic nutrient needed in the diet of a living thing. Pages 73, 78, 80-83, 85-86, 88, and 159.

**Mineral spirits -** Liquids similar to gasoline but slower to burst into flame. Mineral spirits are commonly used to thin paint. Page 176.

**Minoxidil -** A drug sometimes used to treat either hypertension or baldness. Page 63.

**Minted -** Made by a press in the same way that a coin is made. Page 162.

**Miscible -** Liquids that will dissolve in each other at any proportion. For example, alcohol will dissolve in water all the way from light beer to gin. Liquids that are immiscible in each other, such as oil and water, will separate into layers rather than dissolve in each other. Page 126.

**Mitochondrion -** The energy-producing compartment in a living cell. The plural is "mitochondria." Page 45.

**Mixture -** More than one type of matter in a material or a region. For example, if you take peas and mix them with mashed potatoes, you get a mixture of peas and potatoes. Pages 3, 17, 28, 46, 60, 64, 66-67, 74, 80, 86, 89, 98-99, 114, 119-125, 128, 130-131, 133-135, 140, 157, 164, 167, 172, 174, 176, 178-179, and 182.

**Moist** - Soaked in water or another liquid. Pages 94, 126, 132, 143, 152, and 156.

**Moisture** - A little wetness. Usually, moisture is mostly water. Pages 60-61, 63, 94-96, 127, 133, 136, 143, 152, and 181.

**Molasses** - A syrup created as a by-product of sugar refining. Page 129.

**Molecule** - The smallest unit of a chemical that retains many of the chemical's properties. Molecules are made of atoms. Most molecules are very, very tiny, but some polymers can be as large as a bowling ball. Page 188.

**Molybdenum** - 1. An element found in certain types of steel. 2. A mineral found in many foods. Pages 81 and 150.

**Monosodium glutamate (MSG)** - A flavor enhancer. Page 66.

**NaOH** - A symbol for the chemical sodium hydroxide. This is actually not a word at all. "Na" is a symbol for "sodium." "O" is a symbol for "oxygen." "H" is a symbol for "hydrogen." "O" in front of "H" often means "hydroxide." "Na" followed by "OH" means sodium hydroxide. As you can tell, this symbol language requires a great deal of effort to learn. The problem is that after mastering it, the hapless chemist still does not know what sodium hydroxide can do (other than react with acids to form sodium salts). Because very few labels use this symbol-speak, this book avoids it. Most beginning chemistry classes spend many hours on this topic. Page 150.

**Naphtha** - A very flammable liquid similar to gasoline. It is used to dissolve away crud. Page 176.

**Natural** - Made by forces not controlled by humans. Pages 2-3, 30, 59-62, 66-67, 69-71, 73, 79, 92, 96, 151-152, and 168.

**Natural gas** - A gas that is burned in some homes to produce heat. It is mostly methane gas. Page 122.

**Nature** - The way the universe works. Pages 1-3, 11, 29, 48, 52-54, 117, 119, 143, and 153.

**Neurotransmitter** - A chemical that sends a message from one nerve cell to another. Page 32.

**Neutral** - 1. Neither acidic nor basic. 2. Neither positive nor negative. Pages 103 and 155.

**Neutralize** - To make inert by adding its opposite. An electric charge can be neutralized by adding an opposing charge — for example, a negative charge can be destroyed by adding positive charges to it. Likewise, a basic solution can be neutralized by adding an acid until the pH of the solution becomes 7 (neutral). Page 189.

**Newton, Isaac** - The best scientist so far. In physics, he contributed to both mechanics and optics. In math, he invented calculus. In chemistry, he made the reflecting surface for his reflecting telescope. Pages 123-124.

**Niacin** - A type of vitamin. Pages 82-83.

**Nickel** - A white metallic element. It can be found in many alloys. Pages 164, 170-171, and 177.

**Nicotine** - The ingredient in tobacco that produces smoker's high and addiction. Pages 98, 108-109, and 151.

**Nitrate** - Part of a chemical name that means the substance contains nitrogen and oxygen. Because plants can use nitrogen from nitrates to grow, nitrates are often used in fertilizers. Pages 104 and 150.

**Nitric acid** - A strong acid that is also a powerful oxidizing agent. This is wicked stuff that is used widely in the chemical industry. It can totally dissolve a pre-1980 penny in about a minute and evolve a toxic gas at the same time. Pages 167 and 176.

**Nitrogen** - A gas that makes up about 78% of the earth's atmosphere. While it is safe to breathe at sea level, at the great pressures common to deep-sea diving, it can cause problems for the divers. For example, the bends is normally caused by bubbles of nitrogen gas in blood. Serious deep-sea divers use gases such as helium, argon, or neon in place of nitrogen. Pages 48, 122, 134, 142, 146, 150, and 152.

**Nitrogen oxides** - Gases made by combining oxygen and nitrogen at high temperatures. When these noxious gases are mixed with sunlight and hydrocarbons such as gasoline, the result is smog. Page 134.

**Nitroglycerin** - An oil used as an explosive, and sometimes, as a type of heart medicine. Page 111.

**Nobel Prize** - The highest award given in the field of chemistry. It is named after the inventor of dynamite, Alfred Bernhard Nobel. Pages 12 and 185.

**Nonflammable** - Does not burn. Page 153.

**Nonionic** - Contains few (if any) charged particles inside the material. Many organic materials such as sugar and gasoline are nonionic. Page 145.

**Nonpolar** - Another word for oil-like. Page 136.

**Nontoxic** - Small doses of it will not cause injury. Pages 94, 146, and 153.

**Noradrenalin** - A stimulant found in the body. Like most stimulants it can increase heart rate and breathing. Page 32.

**Nuclear energy** - Energy from changes in the nucleus of matter. Unlike other forms of energy, it involves measurable conversion of matter into energy. Page 44.

**Nuclear power** - A method of creating power that changes tiny amounts of matter into energy. Pages 19, 110, and 113.

**Nutrient** - A chemical needed in food to avoid one or more diseases. Pages 40, 73, 77-78, 80, 83-85, and 150.

**Octane** - A measure of how likely it is for a fuel to "knock" in a gasoline engine. Pages 123-125 and 179.

**Octane number** - A number that is normally between 0 and 100 that measures how likely it is for a fuel to "knock" in a gasoline engine. A fuel with a low number is very prone to knocking while a high octane number indicates that the fuel rarely knocks. Pages 124-125 and 179.

**Oil** - A fluid that dissolves in gasoline but not in water. Different types of oils are used for cooking and keeping an engine lubricated. Pages 14, 17, 19, 55-57, 60-61, 66-67, 74, 76, 78-79, 86, 98-99, 101, 114, 118, 122, 125, 128-130, 134, 136, 138, 151, 154, 159, 178-179, and 182-184.

**Oiling** - Applying a greasy or oily material to a surface. Oiling a dish can reduce the chance of food sticking to the dish. Page 73.

**Oil-soluble** - Able to dissolve in an oil. Oily materials such as gasoline and natural gas tend to be oil-soluble. Pages 82 and 106.

**Opposite charges attract.** - A pithy rule that explains most of electronics. This is the reason why electricity flows from one place to another — the charges at the two places are attracted to each other. Page 148.

**Optimum** - An impressive word that means the same thing as "best." Page 125.

**Ordered** - 1. Everything in its place. 2. Like a crystal. Liquids are more ordered than gases. Page 153.

**Organic** - 1. Something vaguely good for the environment (or at least claims to be). 2. Something from a living thing. 3. Most chemicals with carbon in them. Pages 26, 79, 97-99, 105, 132, 136-137, and 189.

**Organic material** - A substance from a living creature or one that is rich in carbon-containing chemicals. Pages 97-98, 132, and 189.

**Osmosis** - A process where solvent goes from dilute solution to where there is more dissolved material. Thus, water tends to go from areas of fresh water into salty water. The phrase "learning by osmosis" is a cliché where the speaker imagines that people learn by the flow of wisdom from those who know what they are talking about. The analogy is apt if you consider wisdom to be the solvent. Wisdom would then flow from those rich in it to those who have little wisdom. The analogy soon breaks down as more factors are considered. Therefore, it is best to avoid using this phrase. Pages 52-53.

**Ounce** - A measure of weight and volume. A regular ounce is 1/16th of a pound. A troy ounce is slightly heavier. Pages 6-7, 10, 15-16, 24, 37, 42, 61, 72-73, 76-77, 97, 109-110, 123, 133, 137, 149, 169-170, and 191.

**Overdose** - Taking too much of a drug. Pages 81-83 and 106-107.

**Oxidation** - Reaction of a chemical with an oxidizer such as oxygen or chlorine. The oxidation of gasoline or other similar fuels by oxygen is called "combustion." Pages 13, 94, 97, 147, and 175.

**Oxidized** - Reacted with an oxidizer such as oxygen or chlorine. Rust is an example of an oxidized material. Pages 58, 136, and 176.

**Oxidizer** - A material such as oxygen gas, chlorine gas, or bleach that will oxidize a fuel. An oxidizer is needed for a fire to burn. The oxidizer for most fires is oxygen gas from the air. Page 147.

**Oxidizing** - Causes oxidation. One oxidizing solution is hydrogen peroxide in water. Pages 74, 105, and 155-156.

**Oxidizing agent** - A chemical such as oxygen or chlorine gas that supports combustion when mixed with a fuel. Pages 105 and 156.

**Oxygen** - A gas that makes up about 21% of air. It is burned along with fuel in fires. Living things also use oxygen to burn food. Pages 13, 45-46, 48-50, 56, 70, 74, 81, 84-85, 95-97, 105, 119-120, 125-126, 132, 134-135, 140, 142, 147, 152, and 156-157.

**Palladium** - A white metallic element with properties close to those of platinum. This metal is used along with platinum as a catalyst in catalytic converters. Pages 171-172.

**Pantothenate** - A salt of the vitamin pantothenic acid. Pages 82-83.

**Parathion** - A type of insecticide. Page 151.

**Particles** - Tiny bits of matter. Molecules, atoms, protons, electrons, and quarks are all examples of particles. Pages 62, 64, 134, and 146.

**Pasteurization** - Heat treatment to kill germs. Page 96.

**Pasteurized** - Exposed to heat to prolong the shelf life of a product. Milk is often pasteurized to keep it from going sour too quickly. Page 70.

**Penicillin** - The first effective antibiotic made by a mold and used as a medicine. Page 112.

**Pesticides** - Chemicals that kill annoying life-forms. Insecticides are one type of pesticide. Pages 96 and 150-151.

**Petrolatum** - A mixture of hydrocarbons with jelly-like texture. It is used as a lubricant and as an ingredient in cosmetics. Page 114.

**Petroleum** - An oily mixture of hydrocarbons found in the earth. It is also called "crude oil." Pages 60, 122, 129, and 179.

**pH** - A measure of acidity. A pH of 1 might be found in a human stomach and is very acidic. A pH of 7 is neither acidic nor basic. A pH of 14 is very basic and might be found in a caustic drain-cleaning solution. Pages 65, 94, 103, 146, and 155-156.

**Phase change** - Change from a liquid to a gas (boiling), liquid to a solid (freezing), solid to a liquid (melting), or solid to a gas (sublimation). Basically, whenever something goes from being solid, liquid, or gas to being one of the other two states of matter, a phase change has happened. Page 51.

**Phenols** - A class of organic chemicals that tend to be weakly acidic. Many phenols are used as antiseptics (germ killers). Page 114.

**Phenylketonuria** - A rare hereditary disease that can produce mental retardation in the sufferer if he or she consumes too much of the amino acid called phenylalanine. Page 69.

**Pheromones** - Chemicals used to alert insects to think about sex. Pages 61 and 151.

**Phlogiston** - An odd essence once thought to be responsible for fires. The theory was discredited more than 200 years ago. Page 13.

**Phosphates** - A group of chemicals that contain phosphorous and oxygen. Phosphates are used by plants and animals for some life processes. These chemicals are also sometimes used to help laundry detergents work better. Page 146.

**Phosphocreatine** - A chemical in human muscles that helps provide the muscles with energy. Pages 45-46.

**Phosphorus** - An element that comes in three different colors. Red phosphorus is the stuff in a match head that lights the match. Phosphorus also goes into plant fertilizer. Pages 81, 146, 150, 152, and 174.

**Photochemical reactions** - Chemical reactions started by exposure to light or ultraviolet radiation. Plants that convert carbon dioxide and water into sugars depend on these reactions, as do photographers. Page 175.

**Photolysis** - A chemical change produced by light or ultraviolet radiation. Photolysis is what causes paints to fade in the sun. Plants use photolysis when they are producing food by photosynthesis. Page 157.

**Physical process** - A change in form without the material being irreversibly changed. Wood carving is a good example of a physical process because the wood changes shape without changing into another material. The melting of an ice cube is also a physical process because the water can later be frozen back into ice. Burning wood is a chemical process rather than a physical process because it is tough to change ashes back into wood. Page 182.

**Physicist** - A scientist skilled in mathematics and interested in the way the physical universe works. Pages 74-75.

**Phytic acid** - A chemical that can remove traces of heavy metals. Page 86.

**Pigment** - A chemical used to color an object. This is the active ingredient in a paint. Page 174.

**Pipette** - A device used to transfer small amounts of a liquid. Medicine droppers are one type of pipette. Page 188.

**Piston** - A moveable wall that provides one surface of a cylinder. In an engine, these pistons move up and down in the cylinders and supply energy to the rest of the car. Pages 120, 123, 130, and 135.

**Plastic** - A group of man-made materials that can be designed to have any of a wide-range of properties. All these plastics are types of polymers.

Polymers also include natural materials such as rubbers, cellulose, and proteins. Pages 9, 16-17, 50, 58, 74, 93-95, 104, 112, 118, 135, 140, 149, 152, 179-180, and 183.

**Plasticizer** - A chemical added to a plastic to keep the plastic soft and bendable. Pages 93-94.

**Platinum** - A white metallic element used as a catalyst in catalytic converters. Pages 171-172 and 174.

**Poison** - A material that can injure or kill a living thing. Pages 3, 56-57, 73, 91-92, 95, 107, 110, and 126.

**Polar** - Water-like chemicals. Polar compounds are likely to dissolve in water. Pages 145-146.

**Pollution** - Something that makes an area less clean or less pleasant. For example, dumping mud onto a sidewalk pollutes the sidewalk. Some types of pollution are loosely defined. Some people say that sound or heat can cause pollution. Pages 14, 119, 128, and 133-135.

**Polyalcohol** - A chemical that has more than one structure characteristic of an alcohol. The most common type of polyalcohol are sugars such as table sugar. Note that while sugar is related to alcohol, it will not cause intoxication as will ethyl alcohol or blindness as will methyl alcohol. Page 64.

**Polyethylene terephthalate (PET)** - A plastic currently used for most two-liter size bottles of soda pop. Page 93.

**Polyhydric alcohols** - Sweet chemicals distantly related to alcohol that can keep foods moist. Page 69.

**Polymer** - Another name for a plastic. Some biological materials such as cellulose and proteins are also polymers. Pages 17, 63, 74, 93-94, and 135.

**Polypropylene** - A type of plastic. Page 179.

**Polystyrene** - A plastic used in some coffee cups (among other things). Page 93.

**Polyunsaturated fats** - Oils found in many plants and fish that react with hydrogen to produce saturated fats. Page 79.

**Pore** - A small hole or opening. Skin has many pores to let sweat out of the body. Filters have many pores to let fluids such as air, gasoline, oil, or water through, but trap solids such as dirt behind. Pages 89, 114-115, 126, and 143.

**Potassium** - 1. A metal that explodes when it touches water. 2. A cationic chemical found in many salts that dissolve in water. Pages 81, 105, and 150.

**Potassium permanganate** - Dark purple crystals that can explode when exposed to organic materials. This chemical is a very strong oxidizer. Like most oxidizers, it can be used for cleaning, bleaching, and killing germs. Page 105.

**Pound** - A unit of mass or weight. A regular pound is slightly heavier than a troy pound. Pages 4-8, 10, 16, 18, 24, 37, 42, 46, 52, 55-56, 71, 80-81, 93, 96, 109-110, 121, 127, 133, 140, 147, 169-170, 183, and 193.

**Powder** - A very finely ground solid. Pages 35, 88, 90, 146, 149-150, and 156.

**Power** - A measure of how much work can be done in a unit of time. Pages 8, 11, 17, 19, 45-46, 49, 105, 110, 113, 116, 118-122, 124, 132, 134-136, 141-143, 147, 153, 172, and 179.

**Precipitating** - Something falling out of a solution. When the solution is the mixture of gases that make up the atmosphere, it is also called "raining." When the solution is a liquid in a test tube, precipitating is solids forming and dropping to the bottom of the tube. Page 114.

**Precipitation** - The process of something forming in a solution and falling down. For example, if water droplets form and fall out of the sky, it is called "precipitation." Crystals forming in a solution of sugar water, and sugar piling up at the bottom of the container is also precipitation. Page 114.

**Prescription** - A written order from a doctor to a druggist to provide someone with medicine. Pages 35 and 115.

**Preservative** - Something that keeps a material (usually a food) from spoiling. Pages 96-97 and 152.

**Pressure** - A force pushing against something. Pressure is very high in the ocean because of the weight of the water. There is little pressure in outer space because there is little gas to push against spaceships or UFO's. Pages 49, 51, 56, 75, 97-98, 119-120, 122-123, 128, 134-135, 139-140, 156, 166-167, and 179.

**Pressurizing** - The act of putting pressure on something. Pressurizing a gas will reduce its volume (the space that the gas occupies). Page 135.

**Process** - 1. A series of connected events. For example, life is a process of birth, growth, reproduction, and death. 2. To subject to some treatment. For example, raw sugar beets are processed to make pure sugar. Pages 5, 14, 42, 45, 48-49, 52, 71, 79, 86, 89, 95-98, 104, 107, 110, 114, 120, 132, 147, 168, 172, 178, 180, and 182-183.

**Producer gas** - A mixture of gases produced by burning fuel with too little oxygen. This gas is mostly nitrogen, carbon monoxide, and hydrogen. In the past, it has been used to power cars. Page 122.

**Proof** - 1. An argument that rules out any reasonable objection. 2. A measure of the alcohol content of a drink. Pages 89-91 and 104.

**Propane** - A gas from crude oil that can be burned to make heat. Pages 56 and 179.

**Propanone** - A chemical more commonly called "acetone." It is used as a solvent for dissolving all sorts of organic chemicals and water as well. It is sometimes used as a nail polish remover. Page 86.

**Propylene** - A flammable gas that is made from crude oil, and in turn, is used to make other chemicals ranging from acetone to polypropylene. Page 179.

**Proteases** - Enzymes that digest protein. Page 148.

**Protein** - A chemical made by combining amino acids. Proteins are used to make some types of tissue and most enzymes. Pages 32, 44-45, 62, 69, 71, 77-78, 80, 82-83, 86-88, 114, 147-148, 153, 175, and 181-182.

**Psi (pounds per square inch)** - A measure of pressure. Atmospheric pressure at sea level is roughly 14.7 psi. The pressure 30 feet below the sea is roughly 30 psi. Page 140.

**Pure** - 1. Made of only one type of chemical. 2. Made of a mixture of relatively safe chemicals. Pages 17, 36, 50, 54-55, 66-67, 86, 89-90, 92, 104, 124, 133, 155, 164-167, 169, 171, 174, 180, 182-183, and 188.

**Purified** - Made more pure. For example, distilling a wine can produce a brandy that is richer (purer) in alcohol. Pages 86 and 89.

**Purify** - To make more pure. Pages 3, 55, 60, and 112.

**Purity** - A measure of how pure something is. For example, distilled water is of higher purity than tap water. Perhaps the material with the highest purity is the silicon used for making computer chips. Before doping with trace impurities, that silicon is very, very pure. Of course, just because

something is pure, does not mean that it is good to eat! Pages 165-167 and 171.

**Pyrethrins** - A class of natural chemicals that can knock a flying insect out of the air. With the insect disabled, a person has the choice of killing the insect; or putting it into a box, driving it to a nearby farm, and setting it free. Page 151.

**Quantity** - Something that can be measured in numbers with units. For example, a quantity of time might be five minutes with "five" being the number and "minutes" being the units. A quantity of mass might be 2.5 pounds. Pages 4-5, 19, 99, 120, 123, 126, 170, and 192.

**Quart** - A measure of volume equal to two pints. A quart of pure water weighs two pounds. Pages 14, 76, and 121.

**Quartz** - A mineral made of the same material as most types of glass. Page 167.

**Radioactive** - Unstable chemicals that spontaneously turn into other chemicals while emitting radiation such as gamma rays or alpha particles. For example, uranium is radioactive because it decays into materials such as thorium, radon, and lead while emitting radiation. Pages 12, 29, 96, and 110.

**Radioactivity** - Energy given off by radioactive things. Read *Trashing the Planet* by Dixy Lee Ray with Lou Guzzo if you want to understand this topic. Page 12.

**Radon** - A toxic gas found in many homes and some nuclear reactors. Page 110.

**Raw materials** - What a worker starts with to make something. Pages 14-15 and 179.

**Reacts violently** - Chemicals producing heat and pressure — for example, dynamite exploding. Page 5.

**Recrystallization** - A way to purify a solid by dissolving it in a liquid and letting crystals of the solid drop out of solution. These crystals tend to be far purer than the original material. Page 183.

**Recycle** - To use something again. Pages 16-17, 93, and 134.

**Red blood cells** - The cells in the human body that provide most of the body with oxygen. Pages 49 and 81.

**Refine** - To remove impurities. Pages 17, 178, and 183.

**Refinery** - A place where raw materials are converted into much purer forms. The most famous type of refinery is an oil refinery. At oil refineries, crude oil is refined into such useful materials as gasoline, jet fuel, diesel fuel, and asphalt. Page 125.

**Reformation** - A technique to increase the octane number of a fuel. It changes hydrocarbons such as hexane into aromatic compounds such as benzene. Page 125.

**Refraction** - A change in the direction of light on passing from one medium to another. Refraction occurs when a beam of light hits the surface of a pool of water. This sort of refraction makes your finger look funny when you stick it into water. Page 166.

**Refractive index** - A measure of how much a material will bend light. Page 64.

**Residue** - The stuff that remains after everything else is gone. Boiling hard water will often leave a residue of lime behind. Pages 66, 74, and 129.

**Resistant** - Needs more of a chemical to cause a reaction. For example, germs that are resistant to an antibiotic can live around quantities of the antibiotic that would kill most other germs. Pages 59, 94, 112-113, 151, 168, and 170-171.

**Resource** - Something that is useful. Until a use for crude oil was found, it was simply an annoyance to some farmers. Now, it is thought of as a resource because it can be used for energy and making plastics. Pages 19 and 122.

**Retinoic acid** - A chemical related to vitamin A. It is used to treat skin problems. Page 115.

**Reverse osmosis** - Doing work on a solution to divide it into a concentrated solution and a dilute solution. The work is needed because the resulting solutions are less random, and thus, counter to the second law of thermodynamics. The work generates heat that keeps the universe from becoming less random. The process of reverse osmosis can change salt water into fresh water. Page 52.

**Riboflavin** - Vitamin $B_2$. A vitamin found in milk. Pages 73 and 82-83.

**Richer** - More of something in a given volume. For example, air that is richer in oxygen can make breathing easier and can support fires for a longer time. Pages 48 and 85.

**Rodenticide** - Something that kills a mouse or rat. Page 150.

**Rose water ointment -** An oil that smells like a rose. Page 114.

**Ruby -** A type of red stone. Page 167.

**Rusting -** Oxygen reacting with iron to form a red, flaky material called rust. Pages 132 and 140.

**Salicylates -** A family of chemicals related to aspirin. Of course, each member of the family has its own properties — in the same way that wood alcohol is different from grain alcohol. Page 59.

**Salt -** 1. A seasoning found in sea water. 2. A chemical that is formed when a base reacts with an acid. Pages 12, 52-53, 65-67, 71-74, 76, 81, 86, 93-94, 97, 103-104, 111, 114, 127, 137, 145-147, 154-158, 168, 176, and 188-189.

**Salt water -** A watery solution with a high concentration of sodium chloride. Pages 52-53 and 59.

**Sand -** Tiny rocks. The most important type of sand is called "quartz sand." This type of sand is made of the same material as glass. Pages 11-12, 17, and 74.

**Sanitize -** To make healthy or free of germs. Bathroom cleaners are supposed to sanitize the surfaces that they clean. Page 157.

**Saponated cresol -** A type of chemical germ killer. Page 105.

**Saturated -** A situation where adding a little more of a chemical will change the appearance of a mixture. For example, when a towel is saturated with moisture, adding a little more liquid to the towel will cause the towel to drip. Another example is adding salt to a saturated brine solution, the extra salt will not dissolve, and the salt crystals will stay at the bottom of the container. Page 79.

**Scale -** 1. The relative size of something. If you make rock candy at home using one pound of sugar, you are doing something at roughly one thousandth the scale that it is done in industry. In many cases, doing things on a large scale is cheaper and better than doing them on a small scale. 2. A device to measure either the pull of gravity on an object or the mass of the object. Pages 71-72, 88, 125, 153-155, and 188.

**Scanning electron microscopy -** A way to study very tiny shapes on a surface. Pages 173-174.

**Science -** A collection of facts obtained through the scientific method. Pages 1, 6, 12-13, 25, 47-48, 55, 58, 64-65, 72, 83-85, 107, 116-117, 121, and 189.

**Scientific jargon** - Words designed to 1) speed communication between people who know a subject and 2) confuse anybody else who is listening. Pages 1, 4-5, 51, and 129.

**Scientific literacy** - The notion that people need to know some science trivia to be good citizens. Page 189.

**Scientific method, the** - A powerful method of creating new factual information. Pages 11-14, 21, 23, and 38.

**Scientific studies** - Investigations using the scientific method to arrive at one or more results. Page 13.

**Scientist** - Someone who creates new theories by using the scientific method. Pages 11-13, 26, 30, 43-44, 66-67, 84, 92, 121, 123, 126, and 188.

**Scum** - Filthy material floating on a liquid. Pages 146 and 148.

**Sea water** - Salty water found in the world's oceans. Pages 52 and 59.

**Second law of thermodynamics** - Every change makes the universe more random. You might think that making a bed makes the universe more ordered, but you would only be looking at part of the picture. The work done by your body while pulling the covers into place creates waste heat from your body. On balance, more disorder is created by making a bed than any order resulting from it (an excellent reason not to make a bed). Likewise, a refrigerator can create an area of cold temperatures and relative order. However, it can only do this by heating the surrounding room and increasing the disorder of the molecules inside the room. The second law of thermodynamics says that the increased disorder of the room is larger than the order created within the refrigerator. Pages 8 and 48.

**Secondary metabolites** - Chemicals produced by a living thing that are not directly needed for life processes. The sulfur compounds produced by a skunk are secondary metabolites. Many skunks have had that part of their body removed and have gone on to live full lives. Many secondary metabolites are used for protection. Page 96.

**Secretes** - Gives off chemicals. For example, a South American frog secretes a terrible poison. Poison ivy also secretes a poison (but less terrible). Many flowers secrete a nectar that bees convert into honey. Only used in glossary.

**Secretion** - A flow of chemicals from an area. Hormones are a secretion from glands. In horror movies, blood is a secretion from almost everything. Pages 30, 57, and 114.

**Sedatives** - Drugs that promote calm. Pages 35 and 40.

**Selenium** - 1. A solid element that comes in a variety of colors. 2. The first name of a compound containing the element. Page 81.

**Semipermeable membrane** - A thin film that lets some chemicals through but stops other ones. Most cell membranes are semipermeable and will let water through but few other chemicals. Page 111.

**Sensor** - A device that senses something around it and reports what it has found to something else. For example, a smoke detector acts as a sensor that can sense smoke in the air and sound an alarm when smoke is found. The person hearing this alarm can decide whether the smoke is a cause for concern. Page 134.

**Serotonin** - A chemical that promotes calm when found in the brain. In most of the rest of the body, it promotes pain and swelling. Because the brain has few pain receptors, serotonin can do this double duty. The human body is full of tricks like this. Pages 32-33, 73, and 90.

**Significant figure** - A digit of a number that is likely to be true. For example, if you tie a rope that is about 50 feet long to a rope that is about 50.111023940045 feet long, you get a rope that is about 100 feet long. The extra precision of measurement of the second rope is worthless when added to the first rope. The first rope may actually be 49 feet long or 51 feet long, and this means the combined rope can be anywhere from 99 feet long to 101 feet long. The length of the first rope has two significant figures. The length of the second rope has 14 significant figures. The combined rope has three significant figures. Pages 20 and 192.

**Silicon** - An element used to make computer chips. Page 168.

**Silver** - A white metallic element used to make some jewelry and coins. Pages 167, 170-172, 177, and 180.

**Simple chemicals** - Chemicals that a chemist finds easy to learn and remember. Pages 2 and 188.

**Sleeping pills** - Pills that help to promote sleep. Pages 33, 35, and 106-107.

**Sludge** - Mud. Page 11.

**Smog** - A form of air pollution found primarily over Los Angeles. Page 134.

**Smoke** - A sooty cloud of carbon products often found coming from a fire. Pages 57, 74, 90, 108-109, 132, and 143.

**Snow** - One form of ice. Pages 50-51, 102, 139, and 181.

**Soap** - Salts of fatty acids. As you can guess, most soaps are made by treating fats with chemicals such as sodium hydroxide. Pages 5, 57, 59, 104, 115, 127, 135, 149, and 167.

**Soda lye** - One of the names for the strong base known to chemists as sodium hydroxide. Page 150.

**Sodium** - 1. A metal that reacts violently with water. 2. A positive ion found in many salts such as sodium chloride. Pages 52-53, 81, 111, 146-147, 149-150, 154-157, and 189.

**Sodium bicarbonate** - Another name for baking soda. This chemical is used in cooking and can help remove odors from a refrigerator. Pages 154-156.

**Sodium carbonate** - A salt that acts like a base when mixed with water. Page 155.

**Sodium chloride** - A salty tasting chemical also known as table salt. Pages 52 and 81.

**Sodium hydrogen sulfate** - A salt that acts like an acid when mixed with water. Page 155.

**Sodium hydroxide** - A chemical called by other names such as soda lye and NaOH. It is a strong base that is used widely in industry and also in household drain cleaners. Pages 150, 157, and 189.

**Sodium metasilicate** - An ingredient in some dishwasher detergents. Page 149.

**Sodium perborate** - A type of bleach for clothing. Page 147.

**Sodium sulfate** - The salt that is formed when sodium hydroxide is mixed with sulfuric acid. This reaction can be started when a drain cleaner rich in sulfuric acid goes down a drain with a cake of sodium hydroxide left by another brand of drain cleaner. While the reaction forms sodium sulfate, the heat that is released by the reaction can send hot sulfuric acid back up the drain. Page 146.

**Soil-suspending agent** - A chemical that helps keep soil from falling back onto clothes. Most laundry detergents use a soil-suspending agent as a builder. Page 146.

**Solder** - 1. A metal or alloy used to join metallic surfaces. 2. Joining metallic surfaces with a solder. Page 180.

**Solid -** Something that keeps its shape. For example, ice can be picked up and even thrown without changing its shape. Water, which is not a solid, cannot be picked up like ice. Water has to be in a solid container to be picked up. Pages 36, 51, 57, 67, 74, 78-79, 95, 97, 114, 118, 122, 129, 140, 149, 171, 179, 182, and 188.

**Solid phase -** Matter that keeps its shape — no matter what the container looks like. Rocks, most furniture, and walls are examples of things in the solid phase. Page 51.

**Soluble -** Able to dissolve in a liquid. Pages 60, 73, 82-83, 87, 101, 103, 106, 127, 137, 148-149, and 183.

**Solution -** 1. An answer. 2. A mixture that is so thoroughly mixed that not even a microscope can tell it is a mixture. Pages 35-36, 53, 63, 98, 101, 103-106, 111, 114-115, 126, 131-133, 137, 143, 145-146, 148-149, 155-157, 169, 177, and 182-183.

**Solvent -** A liquid that can dissolve other things. For example, water is considered to be close to a universal solvent because it can dissolve so many solids such as salts and liquids such as alcohols. Pages 26, 91, 97-98, 135-137, 175-176, and 182.

**Solvent extraction -** A way to purify a chemical by dissolving it in a liquid and then evaporating the liquid. This process leaves behind impurities that are not soluble in the liquid. Page 182.

**Sonority -** Able to produce a rich sound. It used to be said that you could tell a U.S. coin was genuine by its sound when dropped. Old coins used to give off a bell-like sound. Try that on a modern (post-1980) penny sometime. Modern pennies lack the sonority of pennies that were made of pure copper. Page 170.

**Soot -** Carbon-containing waste products from fires. Pages 3, 134, and 142.

**Sorbitol -** A sugar similar to table sugar but less sweet. Pages 64 and 69.

**Sour -** 1. Rich in acid. 2. Crude oil that is rich in sulfur. Pages 65, 94, 152, and 178.

**Space -** A place where something can be. Pages 2, 7-8, 56, 64, 143, 146, 149, 154, and 167.

**Specific gravity -** The ratio of the density of a material to the density of water. A dense material such as mercury has a high specific gravity while a gas such as helium has a small specific gravity. Page 166.

**Stimulant** - Something that promotes excitement. Pages 32, 36-37, and 40.

**Stone** - 1. A rock. 2. A valuable rock. 3. A measure of weight equal to 14 pounds. Pages 165-167.

**Straight-run fuel** - Fuel that comes straight off the distillation tower at an oil refinery without cracking and reforming. This type of gasoline or diesel fuel tends to be of very poor quality. Page 125.

**Strong bases** - Chemicals that can raise the pH of water up to 14. These bases can often eat away at skin — so be careful around them! Page 150.

**Sublimation** - Changing from a solid into a gas without turning into a liquid first. Pages 95 and 97.

**Substance** - A chemical or mixture of chemicals. Pages 30, 91, and 114.

**Sugar** - One of a variety of simple carbohydrates. The most common type of sugar found on kitchen tables is called "sucrose." Pages 16, 33, 45, 48-50, 65, 69-74, 78, 86, 88-90, 92, 97, 99, 107, 180-181, 183, and 188.

**Sulfur** - An element that is a yellow solid when it is pure. It is also called brimstone. Some preachers have pictured hell as being filled with fire and brimstone. The picture is not pleasant because sulfur burns to give a smelly gas called sulfur dioxide. Pages 63, 150-151, and 178.

**Sulfur-containing compounds** - Some of the smelliest chemicals on Earth. Rotten eggs and skunks give off sulfur-containing compounds. Page 63.

**Sulfuric acid** - An acid that is used widely in chemical plants. The closest that most people come to it is in car batteries where it is mixed with water to produce battery fluid. Sulfuric acid is the reason why battery fluid is so corrosive. Pages 131-133 and 150.

**Supercritical fluid** - A substance in a fluid phase that is under significant pressure and is above the critical temperature for that chemical. A fluid of this sort is somewhere between a liquid and a gas. Page 98.

**Superphosphate** - A type of fertilizer that is rich in phosphorous. Page 152.

**Surface active agent** - A chemical that changes the surface of a liquid. More commonly called a surfactant. Page 145.

**Surface tension** - The force applied to the liquid's surface by the liquid under the surface. This force stretches the liquid's surface tightly, like a

drum. Surface tension is the basis for a series of parlor tricks such as floating a pin on top of liquid water. Page 62.

**Surfactant** - A chemical that changes the surface of a liquid. Pages 62, 145-146, and 148.

**Suspend** - To hang in the middle of a fluid such as air or wash water. As long as dirt is suspended, it will not fall back onto the clothing and make the clothes dirty again. Page 64.

**Sweet** - 1. Tastes like sugar. 2. Crude oil that is low in sulfur. Pages 65, 69, 84, 178, and 180.

**Synthesis** - A way to make something. Pages 32 and 122.

**Synthesis gas** - A gas produced by heating coal with steam. It is rich in carbon monoxide and hydrogen gas. The gas is then converted into useful chemicals such as gasoline or methanol. Page 122.

**Synthesized** - Made by putting things together. Page 32.

**Synthetic** - Made by humans. Pages 61, 70, 112, 130, 166-168, and 179.

**Synthetic dye** - A pigment that was created by one or more artificial chemical reactions. Synthetic dyes from coal tar started the chemical industries in England and Germany. Pages 70 and 112.

**System** - A group of things that work together. Pages 25, 30, 36-38, 41, 44-48, 62, 71-72, 90, 101-102, 111, 113, 119, 124-125, 130-131, 133-134, 136-137, 146, 169-170, and 184.

**Table salt** - The salt commonly added to food to improve the food's taste. It is also called "sodium chloride." Pages 52, 65, 81, 146, 157, and 188.

**Table sugar** - Sucrose. This is the stuff that people put into their coffee, cereal, cookies, pancakes, jams, and many other foods. Pages 69 and 78.

**Tannic acid** - A group of plant chemicals used in dyeing and tanning (among other things). These chemicals are also used to slow bleeding from wounds. Page 114.

**Tannins** - A group of plant chemicals used in dyeing and tanning (among other things). These chemicals are also used to slow bleeding from wounds. Also called "tannic acid." Page 114.

**Tap water** - Water that has passed through plumbing. Pages 5, 130, and 149.

**Tar** - A gooey, oily mess. Pages 49, 66-67, 70, and 108.

**Tarnish** - 1. To dull the luster of something. 2. The chemical on a surface that tarnishes an object. For example, silver tarnish is usually a chemical made of silver and sulfur. Pages 166 and 169-171.

**Temperature** - The measured level of heat of an object. Pages 7-8, 18, 30-31, 34, 41, 51, 54-56, 60, 74-75, 78, 89, 93-95, 97-98, 104, 114, 118, 121-122, 127, 129-130, 132-134, 137-138, 140-141, 143, 150, 154, 168, 175, and 183.

**Terminal** - One end of a battery. Pages 131-132.

**tert-Butyl alcohol** - An alcohol used to poison ethyl alcohol. It is also used as a solvent for various purposes and can increase the octane rating of gasoline. Page 91.

**Test tube** - A piece of lab glassware that nicely holds a small amount of liquid. Pages 2 and 188.

**Testosterone** - A hormone common in men. Page 46.

**Tetraethyl lead** - A compound of lead that used to increase the octane rating of gasoline. It has been outlawed in the United States because of health concerns. Page 126.

**Texture** - How something feels. For example, sandpaper has a rough texture while ice cream has a smooth texture. Pages 69-70 and 95.

**Theobromine** - A stimulant found in cocoa and chocolate. Page 37.

**Theophylline** - A stimulant found in tea. Page 37.

**Theory** - A way of thinking about a subject that adequately explains what is known on that topic. Pages 11-13, 26, 29-30, 77, 85, 162, and 177.

**Theory of oxidation** - The accepted explanation for what happens in a fire and other related processes. Page 13.

**Thermodynamics** - A branch of science that explains and predicts changes among forms of energy and predicts if a reaction will go under certain conditions. For example, a chemist skilled in thermodynamics can predict if two chemicals such as oxygen and hydrogen will react with each other to form water. As long as there is a spark around, the hydrogen and oxygen will react to form water and an explosion. (This reaction makes rockets fly.) If the two gases are mixed without a spark around, thermodynamics will not apply because the reaction goes too slowly to be measured. Pages 8, 48, 75, and 119.

**Thiamin -** Vitamin $B_1$. It is needed in a human's diet. Pages 73, 82-83, and 86.

**Thickener -** A chemical added to a fluid such as water to make the fluid more viscous. This can make the fluid easier to handle. Page 149.

**Tin -** A metallic element used in alloys and as a plating material. Page 172.

**Tincture -** Medicine in a solution of ethyl alcohol. Page 105.

**Titanium -** A strong, lightweight metal that resists corrosion. Page 50.

**Tolerance -** The capacity to endure something. For example, a high tolerance for a drug lets the user take a lot of it without being affected by it. Pages 37, 42, 106, and 193.

**Tonality -** 1. The way some colors look. 2. The way a bit of music sounds. Page 174.

**Touchstone -** A rock of black quartz used to test the purity of gold and silver. Page 167.

**Toxic -** Able to hurt someone. Pages 3, 53, 83, 91, 94, 104, 106, 110, 125, 146-147, 151, and 155-156.

**Trace materials -** Impurities that are present at small but detectable levels. Page 178.

**Translucent -** Something that lets light pass through but scatters the light enough so that things look cloudy. Pages 64 and 93.

**Transparent -** Something that can easily be seen through. Some types of glass and many plastic wraps are transparent. Pages 61, 63, 94, and 175.

**Trichlorethane -** A type of fat-soluble liquid. It is sometimes used to extract oily materials out of a mixture. Page 97.

**Triglyceride -** A fancy word that means a fat or oil. Pages 78-79.

**Troy weights -** A system used mostly for weighing precious metals and jewels. Pages 169-170.

**Ultraviolet (UV) light -** High-energy, invisible radiation that causes skin tanning in humans. Pages 58-59, 140, 146, 173, and 175-176.

**Unit volume -** The volume in a cube with edges that are one unit long. A unit volume called a "cubic centimeter" has edges that are one centimeter long. A unit volume called a "cubic foot" is a cube with edges that are one foot long. Page 52.

**Units** - How things are measured. For example, time is measured in fortnights, length is measured in furlongs, and eggs are measured by the dozen. Pages 4-7, 10, 18-20, 24, 26, 52, 72, 102, 107, 121, 155, and 170.

**Unsaturated** - Organic chemicals with less hydrogen than hydrocarbons such as butane or gasoline. Under the right conditions, unsaturated compounds will react with hydrogen gas to become saturated chemicals. Pages 78-79.

**Urea** - A chemical found in human and animal excretions that is rich in nitrogen. It is often used as a fertilizer. Pages 105, 154, and 156.

**Urushiol** - The active ingredient in poison ivy. Pages 56-57.

**Vaccination** - Treatment with a weak virus to prepare the body to fight a deadly virus. Page 109.

**Valium** - A brand name for a widely used drug that promotes calm. Page 35.

**Vapor pressure** - The amount of pressure that needs to be placed on a liquid to keep it from rapidly evaporating. This pressure changes as the temperature changes. If water is heated to 212 degrees Fahrenheit, its vapor pressure becomes one atmosphere. At room temperature, water's vapor pressure is well below one atmosphere. Page 179.

**Vaporize** - Change from a solid or liquid into a gas (vapor). Pages 67, 89, and 174.

**Varnish** - A colorless coating that protects something. Also, the solution of resin in oil that is applied to create the coating of varnish. Pages 135-136, 173, 175-176, and 182.

**Vat** - A very large tub. Pages 88-89 and 112.

**Vinegar** - An acid produced when alcohol is oxidized. Pages 57 and 176.

**Virus** - A complex chemical that can take over living cells to reproduce itself. Pages 3 and 109.

**Viscous** - High-viscosity. An example of a viscous liquid is honey that pours much more slowly than water. Some people refer to viscous liquids as "thick" liquids. Pages 118 and 129.

**Viscosity** - How slowly a liquid flows in response to a force. High-viscosity fluids, such as honey, pour slowly while low-viscosity fluids, such as water, pour quickly. Pages 129 and 178.

**Viscosity rating** - A measure of the resistance to flow of a liquid. Page 129.

**Vitamin A** - A fat-soluble vitamin that helps prevent night blindness. Pages 82-84.

**Vitamin $B_6$** - One of the nutrients needed by the human body. Pages 32-33 and 82-83.

**Vitamin C** - A nutrient commonly found in citrus fruits. Pages 2 and 82-85.

**Vitamin D** - A fat-soluble vitamin that can be produced by the skin. Pages 82 and 114.

**Vitamin E** - A fat-soluble vitamin that is also used as an antioxidant. Pages 82, 84, 101, and 116.

**Vitamin K** - A fat-soluble vitamin that helps with blood clotting. Pages 82-83 and 101.

**Vitamins** - A group of chemicals that are needed in a human diet. A deficiency in one or more vitamins can cause diseases. Pages 2, 32-33, 73, 78, 82-87, 97, 101, 114, and 116.

**Volatile** - The tendency to quickly evaporate. Butane and gasoline are two examples of volatile liquids. Pages 55-56, 67, 124-125, and 141.

**Volt** - A unit that measures how much an electrical charge wants to move from one place to another. A six-volt battery has a bigger potential than a two-volt battery. Pages 26-27.

**Voltage** - A measurement of the tendency of electricity to travel from one place to another. Except in superconductors, this tendency encounters resistance from the stuff in-between. Pages 8, 26, and 132.

**Volume** - The amount of space in a region. For example, one liter of water takes up 1,000 cubic centimeters. If a cube that size was filled with gasoline, you would have one liter of gasoline. Pages 5, 15, 49, 51-52, 90, 102, 111, 120-121, 127, 129, 135, and 156.

**Waste** - Useless leftovers from a process. As uses are found for waste, the waste becomes by-products with some value. For example, coal tar was a waste product from burning coal. When William Perkin discovered that it could be used to create a valuable dye named "mauve," the coal tar suddenly became a by-product. Pages 8, 11, 60, 114, 120, 135, 138, 149, 152, and 156.

**Water** - A liquid that covers much of the Earth. People use water for drinking and washing. It is arguably the most important chemical because living cells contain a lot of water. Pages 2-3, 5, 11, 16, 18-19, 36, 41, 45, 51-57, 59-60, 66, 70-71, 73-76, 79-80, 84, 86-90, 94-98, 102-105, 110-111, 114, 119, 121, 125-127, 129-133, 136-137, 143, 145-150, 153-157, 166-168, 175-176, 179, 181, 183, and 188-189.

**Watered down** - Made more dilute by adding water. Page 5.

**Water-soluble** - A property of a chemical that makes it more likely to dissolve in water. Of course, temperature is also important, and most solids are more soluble in hot water than in cold water. Pages 73, 82-83, and 103.

**Watery solution** - A mixture of other chemicals with water that is so thoroughly mixed that not even a microscope can see regions of pure chemicals. Pages 36, 98, and 137.

**Wavelength** - The distance until a wave begins to repeat itself. A calm sea with long, rolling waves has waves with long wavelengths while a choppy sea has shorter wavelengths. Electromagnetic radiation such as light also has wavelengths. Blue light has shorter wavelengths than red light. In the case of electromagnetic radiation, the shorter the wavelength; the higher the energy of radiation. Pages 173-174.

**Wax** - A oily semisolid. Pages 60, 93, 135, and 140.

**Weight** - 1. A measure of the pull of gravity on something. 2. A measure of how viscous an oil is. For example, 5-weight oil would be rather runny while 40-weight oil would be far more viscous (thick). Pages 4, 6 , 16, 30, 37, 45-47, 50, 80, 109, 121, 129, 168-170, 180, 183, and 193.

**White gold** - An alloy of gold and palladium. Page 172.

**Wood alcohol** - Another name for "methanol." This liquid boils at a lower temperature than ethyl alcohol and causes blindness in most people if swallowed. Pages 91 and 125.

**Work** - The use of force to move something. Pages 8, 41, 43-44, 46-49, 75, 79, 111, 114, 117-118, 120-121, 129, 131, 139, and 154.

**X rays** - A type of high-energy electromagnetic radiation. Pages 166 and 172-174.

**X-ray fluorescence** - A type of analytical method that exposes a sample to X rays. It can detect various chemicals at the surface with only minimal damage to the item. Page 172.

**Xylitol** - A type of sweetener. Page 69.

**Zeolites** - Minerals found in nature that have many channels through them. Page 143.

**Zinc** - 1. A metal that reacts with acids to produce hydrogen gas. This metal is also alloyed with copper to form brass. 2. A cationic chemical found in some salts used as astringents. Pages 81, 114, 150, 172, and 176.

**Zircon** - A mineral used for various things — including cheap jewelry. Page 167.

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